US011956585B2

(12) United States Patent
Zhang et al.

(10) Patent No.: US 11,956,585 B2
(45) Date of Patent: Apr. 9, 2024

(54) **BLUETOOTH EARPHONE**

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(73) Assignee: **HUAWEI TECHNOLOGIES CO., LTD.**, Shenzhen (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 162 days.

(21) Appl. No.: **17/771,576**

(22) PCT Filed: **Oct. 14, 2020**

(86) PCT No.: **PCT/CN2020/120866**

§ 371 (c)(1),
(2) Date: **Apr. 25, 2022**

(87) PCT Pub. No.: **WO2021/082916**

PCT Pub. Date: **May 6, 2021**

(65) **Prior Publication Data**

US 2022/0417636 A1 Dec. 29, 2022

(30) **Foreign Application Priority Data**

Oct. 31, 2019 (CN) 201911056997.1

(51) **Int. Cl.**

H04R 1/10 (2006.01)
H01Q 1/48 (2006.01)
H01Q 1/50 (2006.01)

(52) **U.S. Cl.**

CPC ***H04R 1/1016*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 1/50*** (2013.01); ***H04R 1/1041*** (2013.01); *H04R 2420/07* (2013.01)

(58) **Field of Classification Search**

CPC H04R 1/1016; H04R 1/1041; H04R 2420/07; H04R 1/1091; H04R 2225/51; H01Q 1/48; H01Q 1/50

See application file for complete search history.

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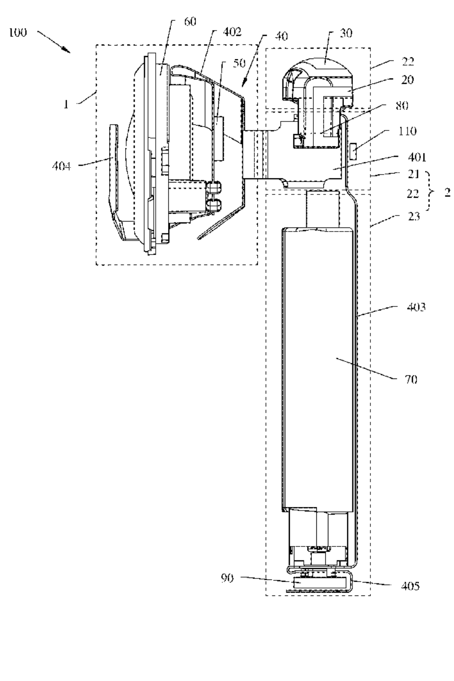
(74) *Attorney, Agent, or Firm* — Maier & Maier, PLLC

(57) **ABSTRACT**

A Bluetooth earphone includes an antenna and a circuit board. The circuit board includes a first grounding branch and a second grounding branch. The first grounding branch is connected in series to a first switch, and the second grounding branch is connected in series to a second switch. When the first switch is on, the first grounding branch serves as a current return path of the antenna. When the second switch is on, the second grounding branch serves as a current return path of the antenna. By controlling the on or off state of the first switch and the second switch, the Bluetooth earphone can switch ground structures of the antenna and select different current return paths for the antenna, to switch radiation patterns of the antenna.

14 Claims, 23 Drawing Sheets



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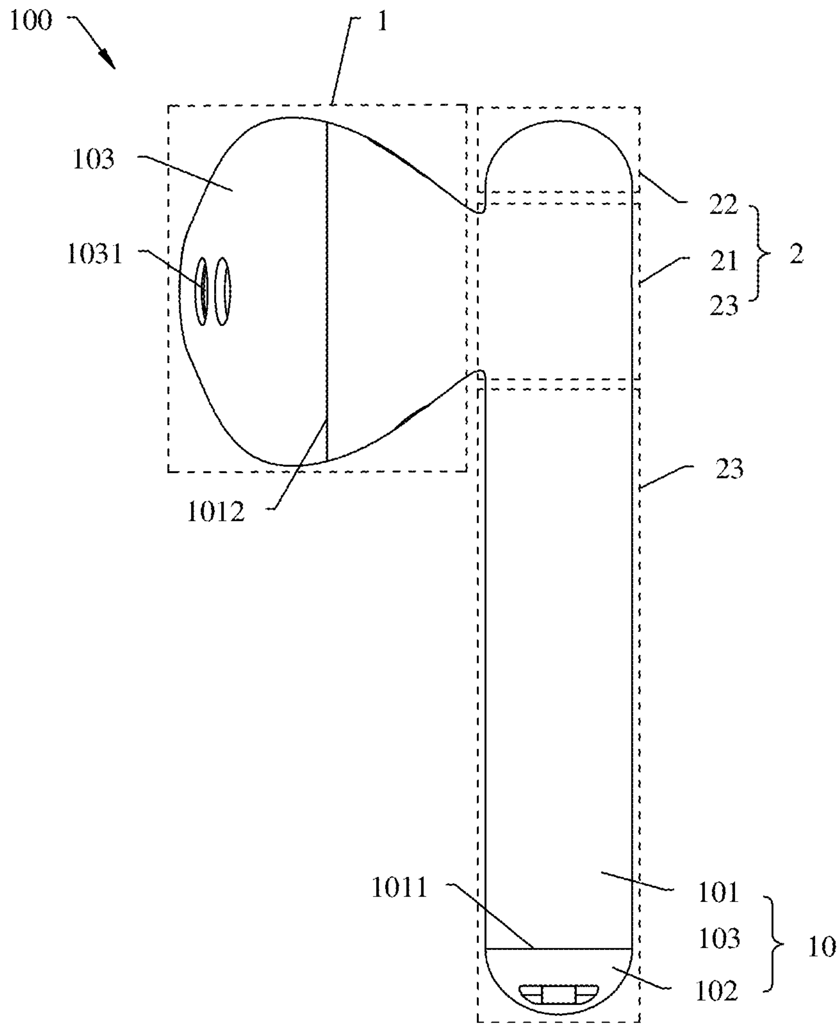

FIG. 1

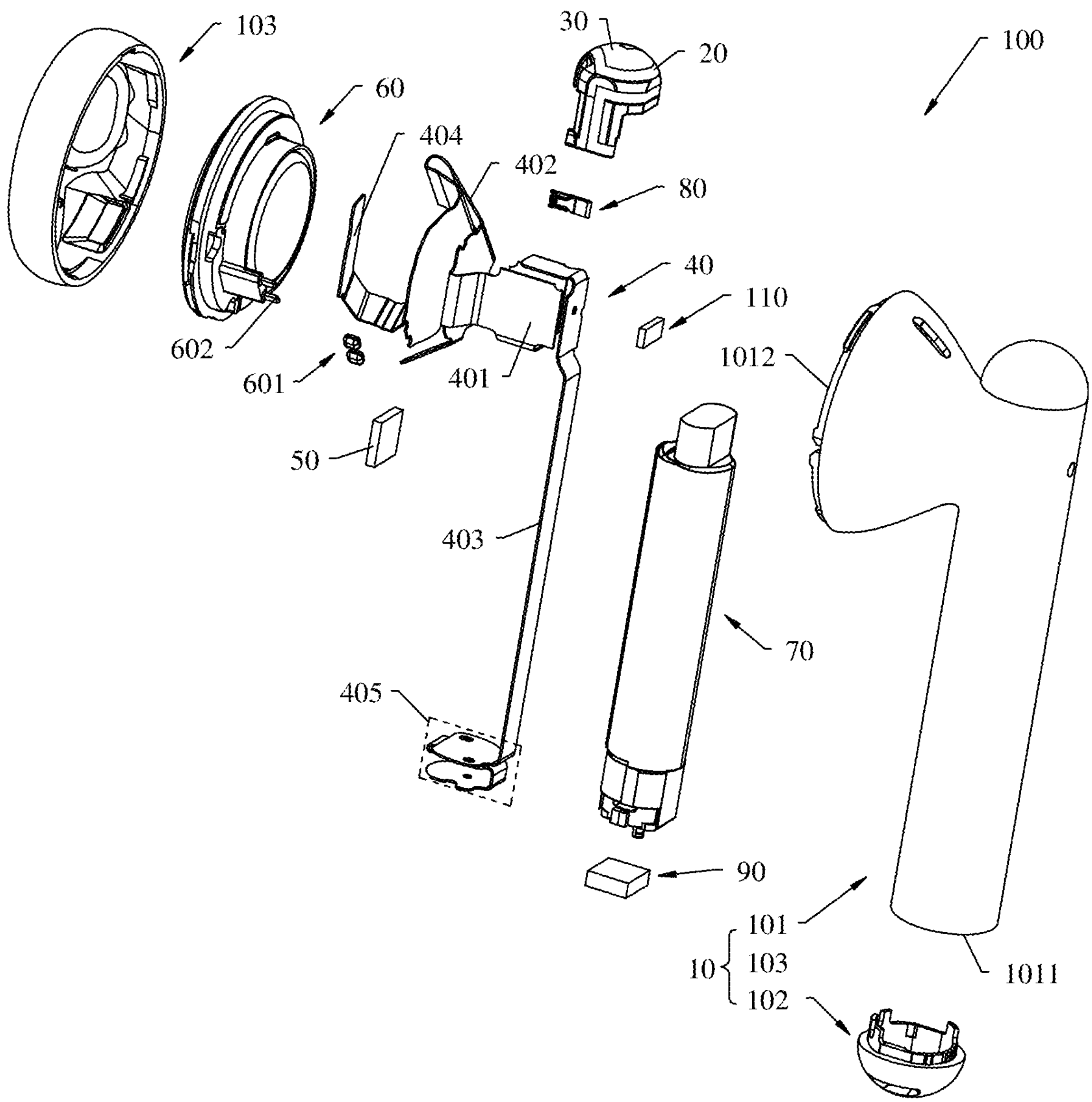
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FIG. 2

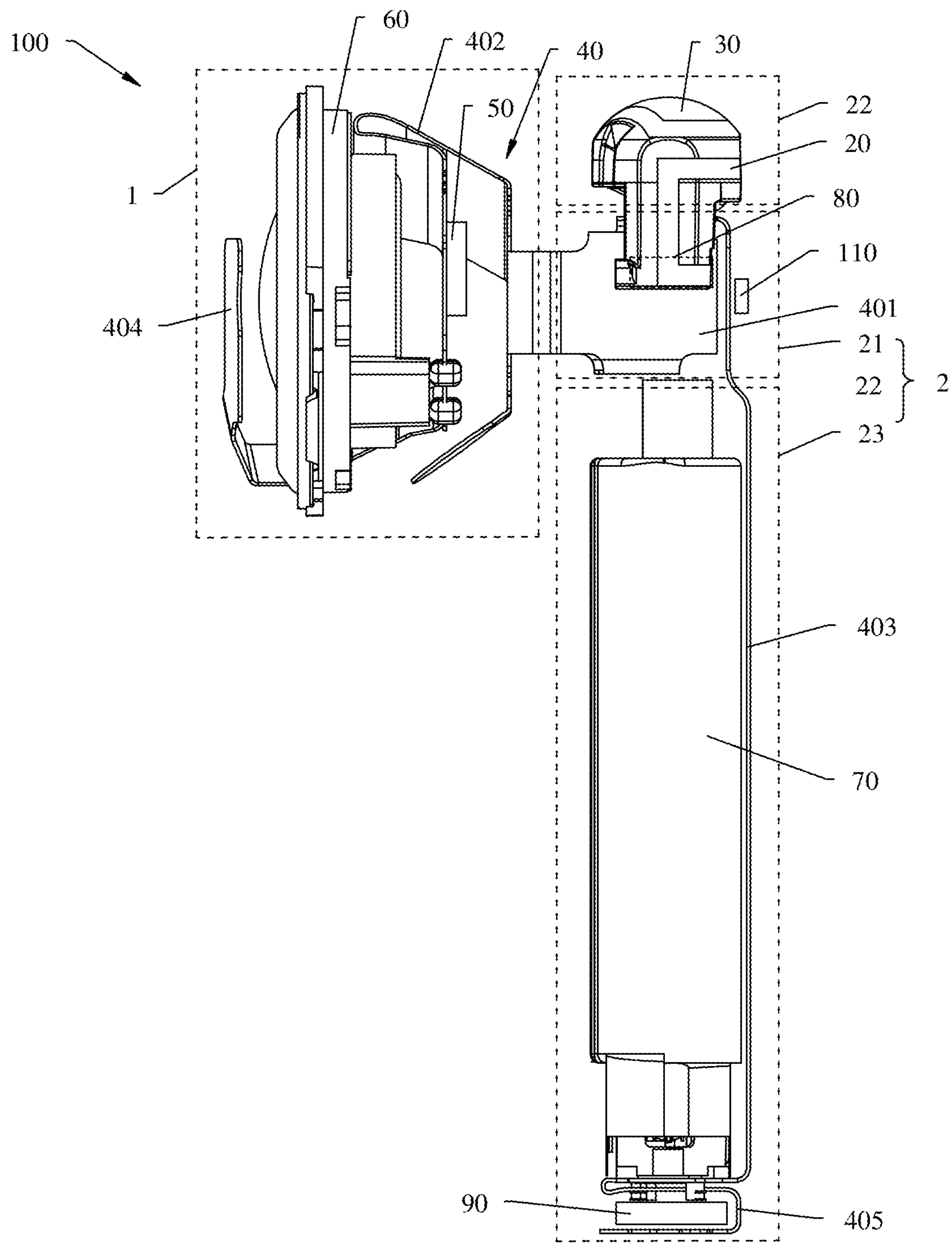

FIG. 3

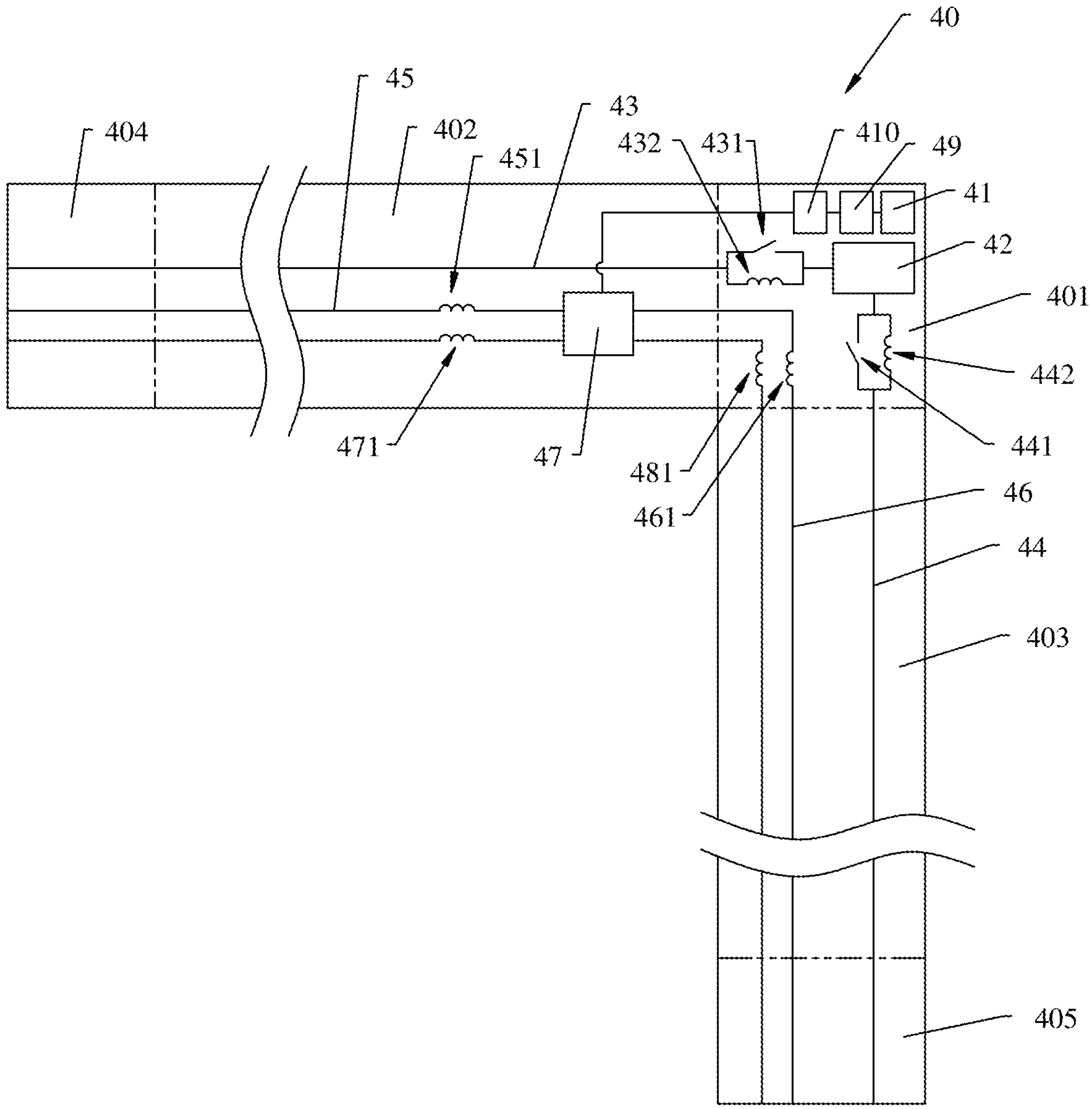

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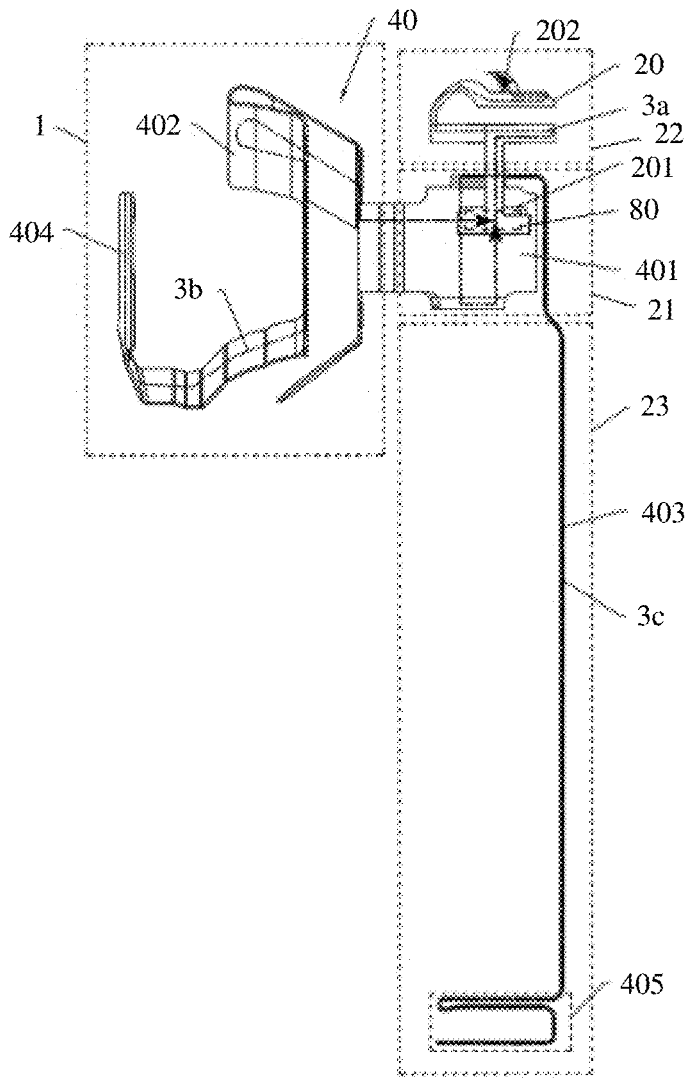
FIG. 4



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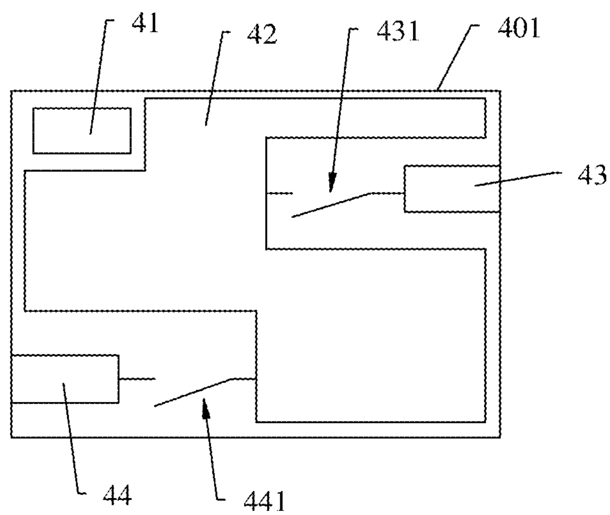

FIG. 6

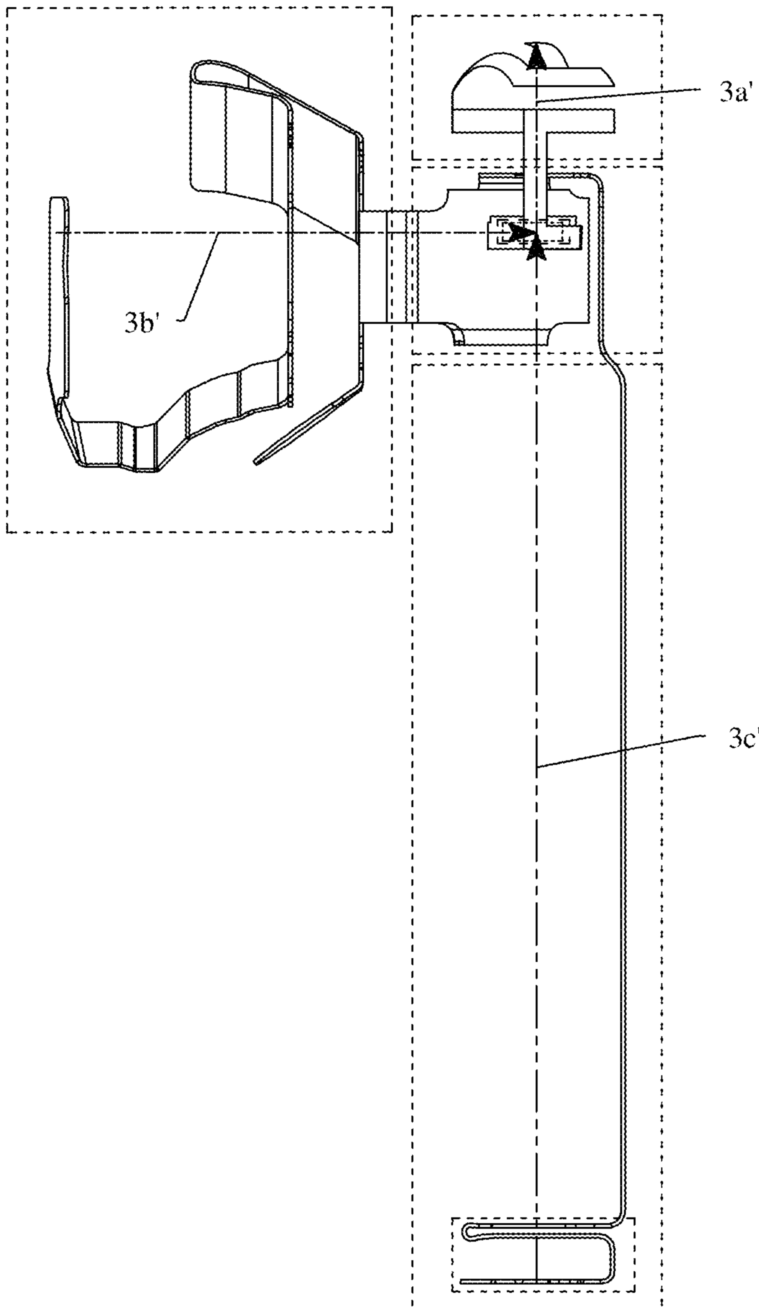

FIG. 7

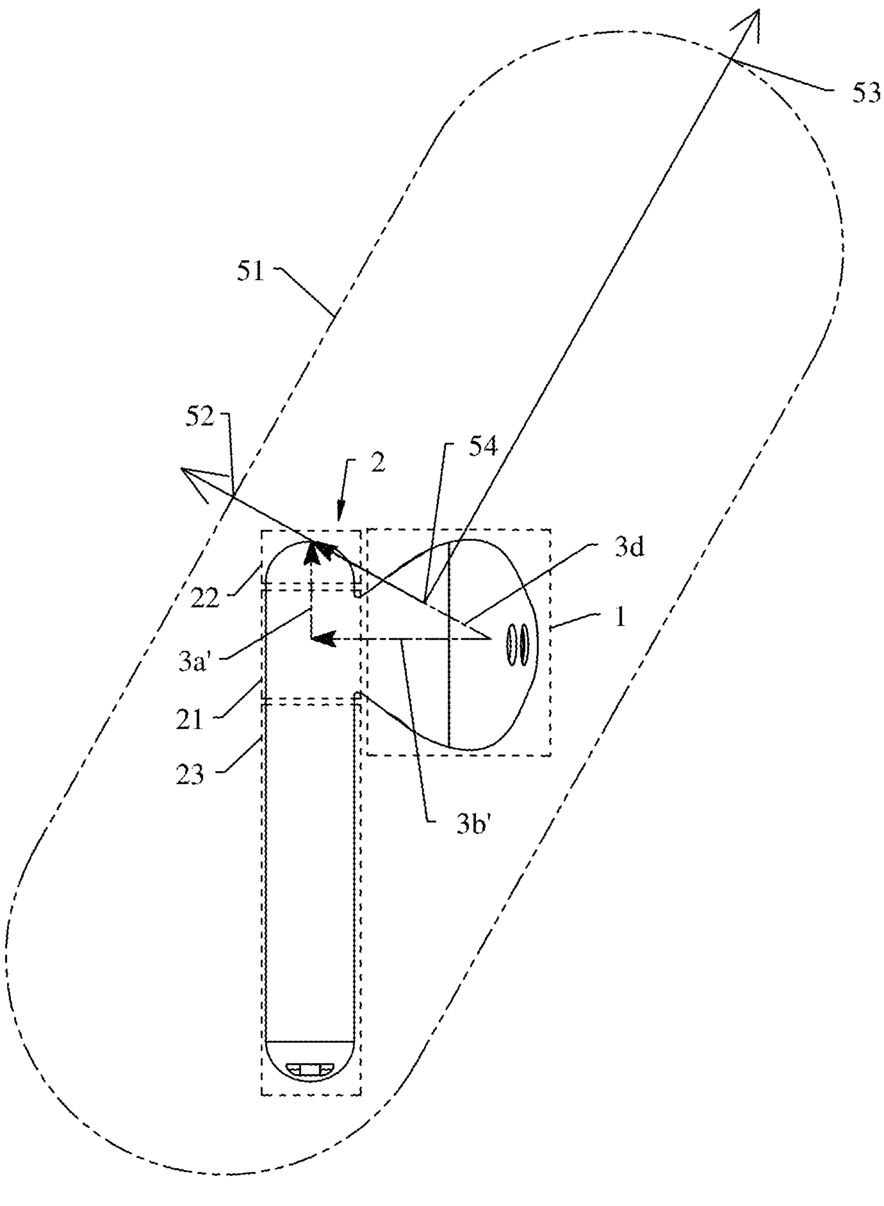

FIG. 8

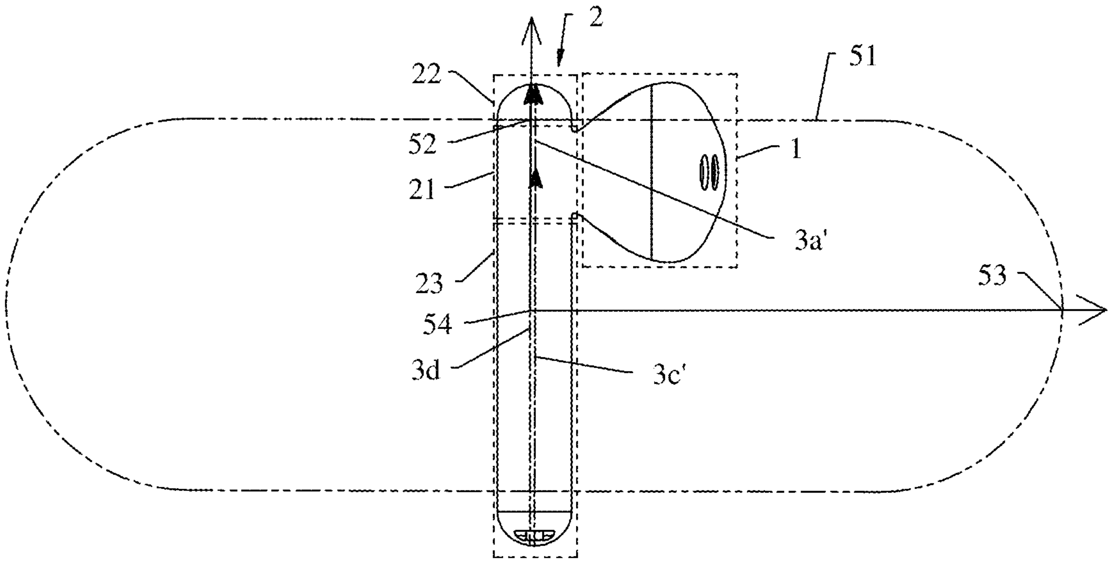

FIG. 9

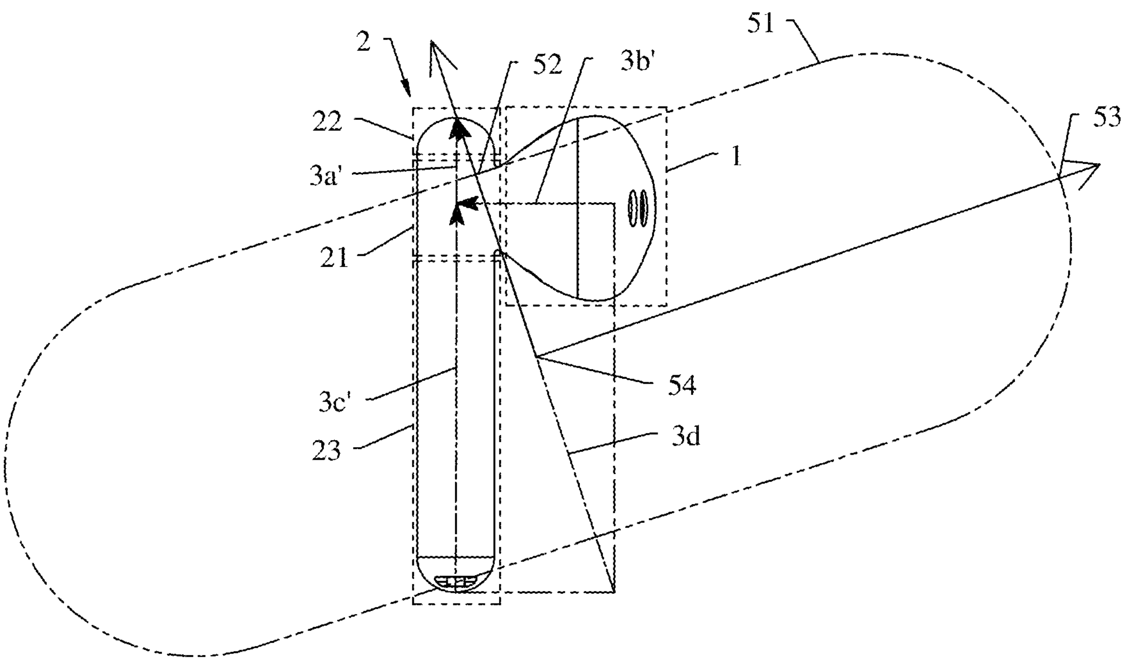

FIG. 10

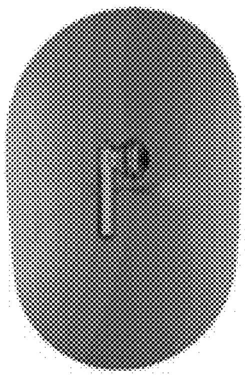

FIG. 11A

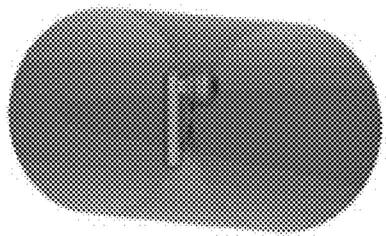

FIG. 11B

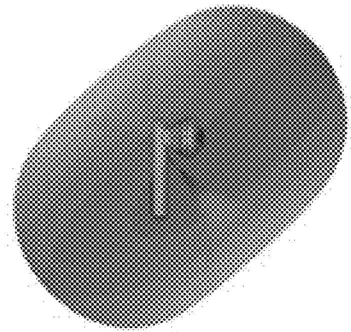

FIG. 11C

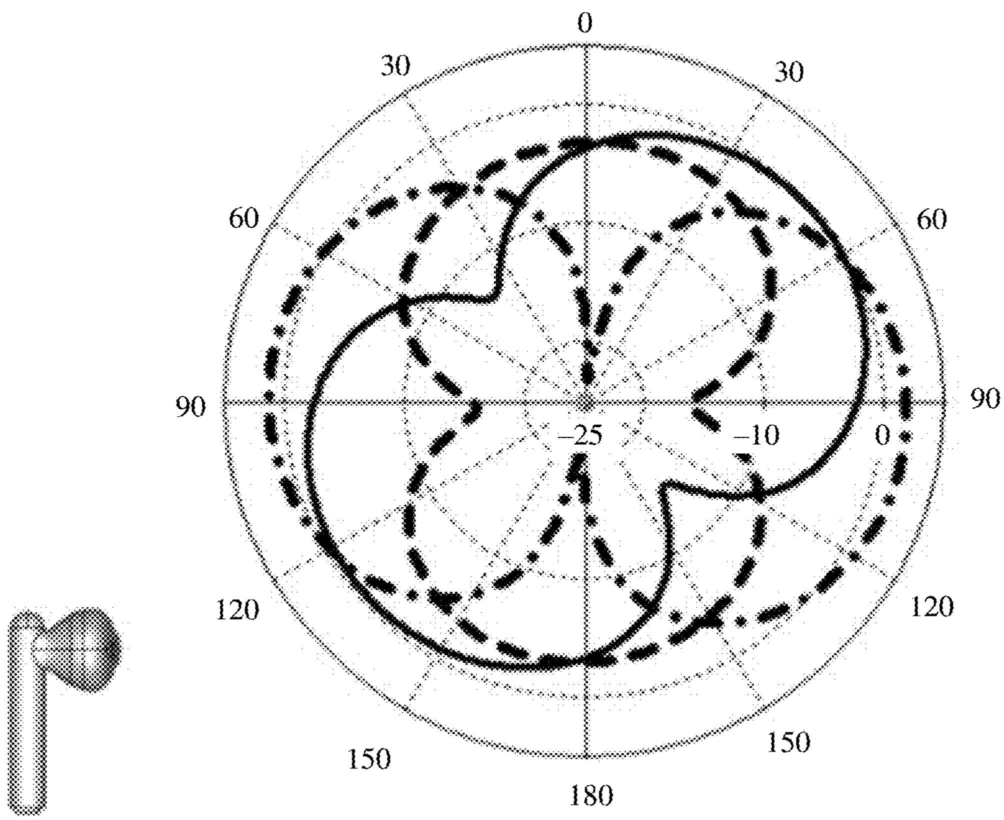

FIG. 12

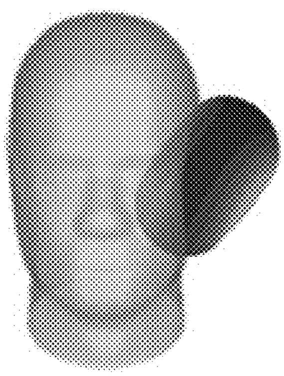
FIG. 13A

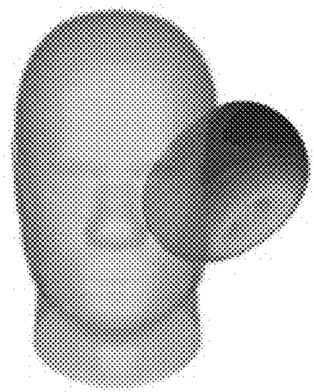
FIG. 13B

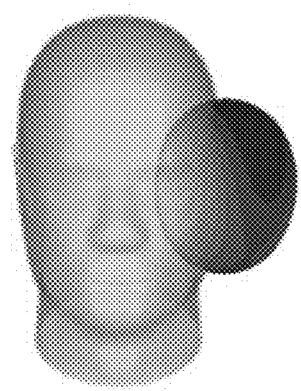
FIG. 13C

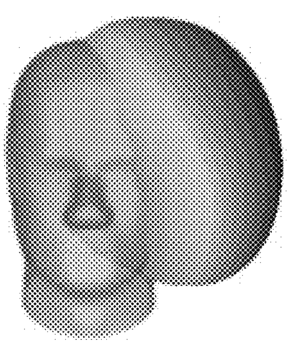
FIG. 14A

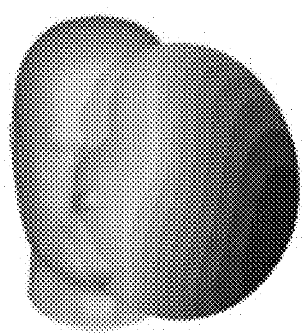
FIG. 14B

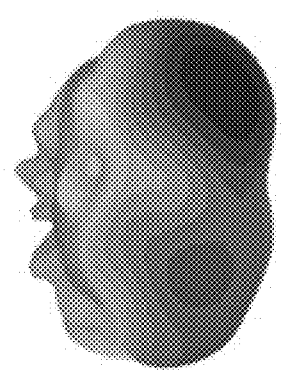
FIG. 14C

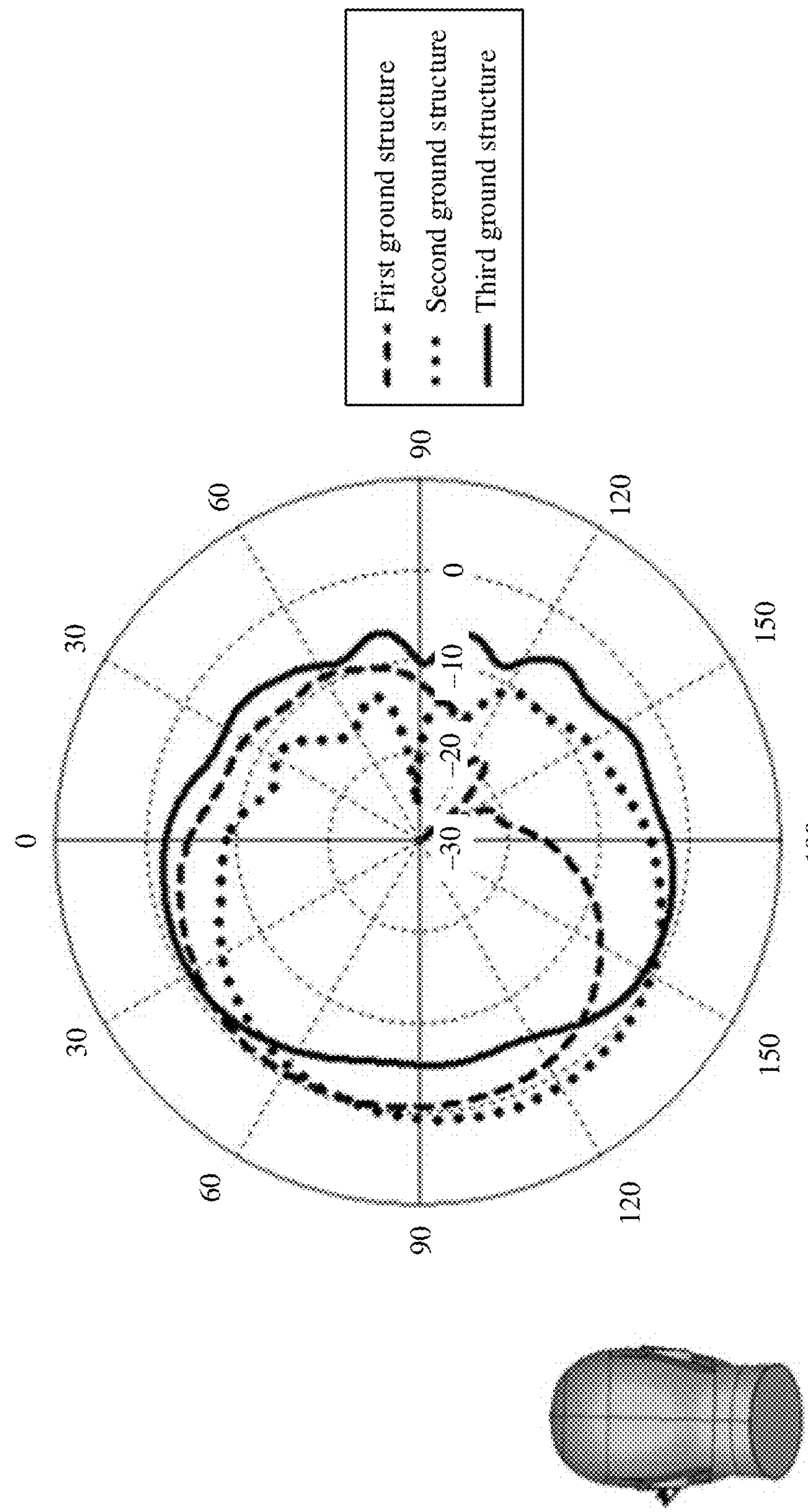
First ground structure
Second ground structure
Third ground structure
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FIG. 15A

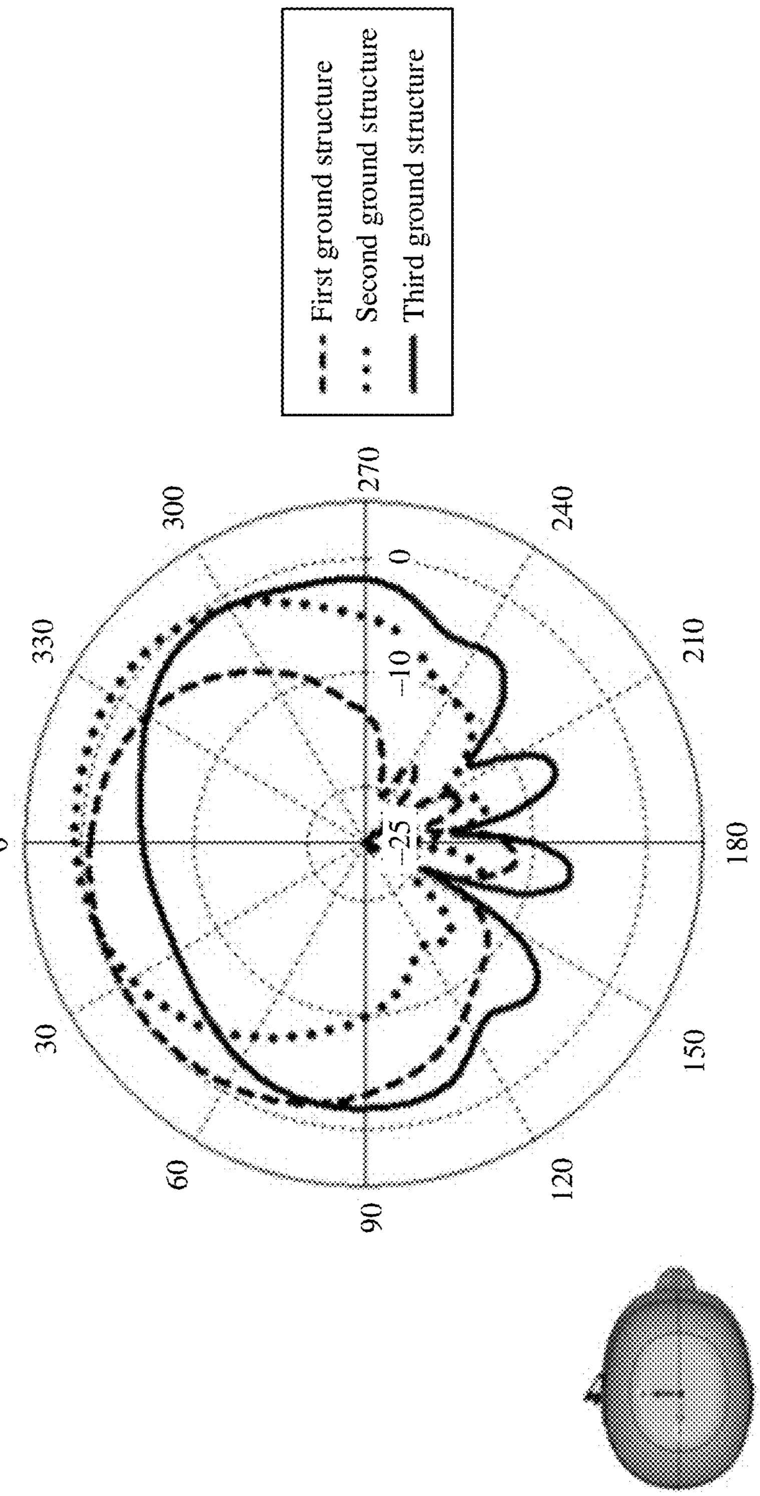
First ground structure
Second ground structure
Third ground structure
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FIG. 15B

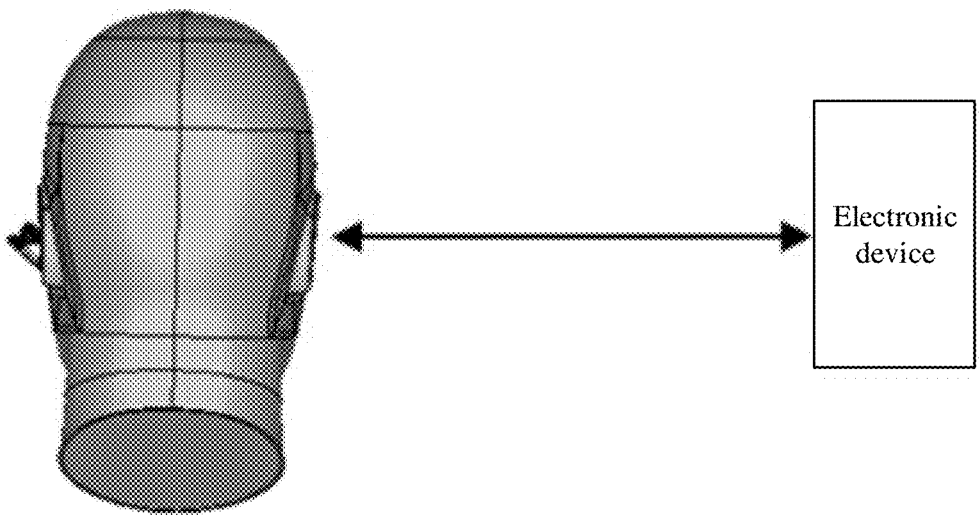

FIG. 16

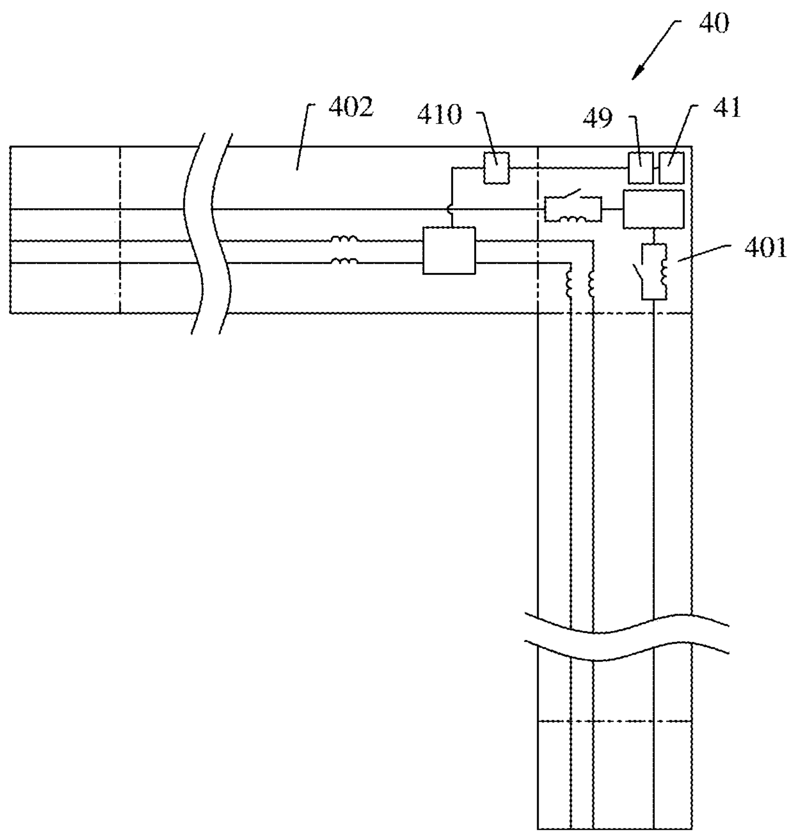

FIG. 17

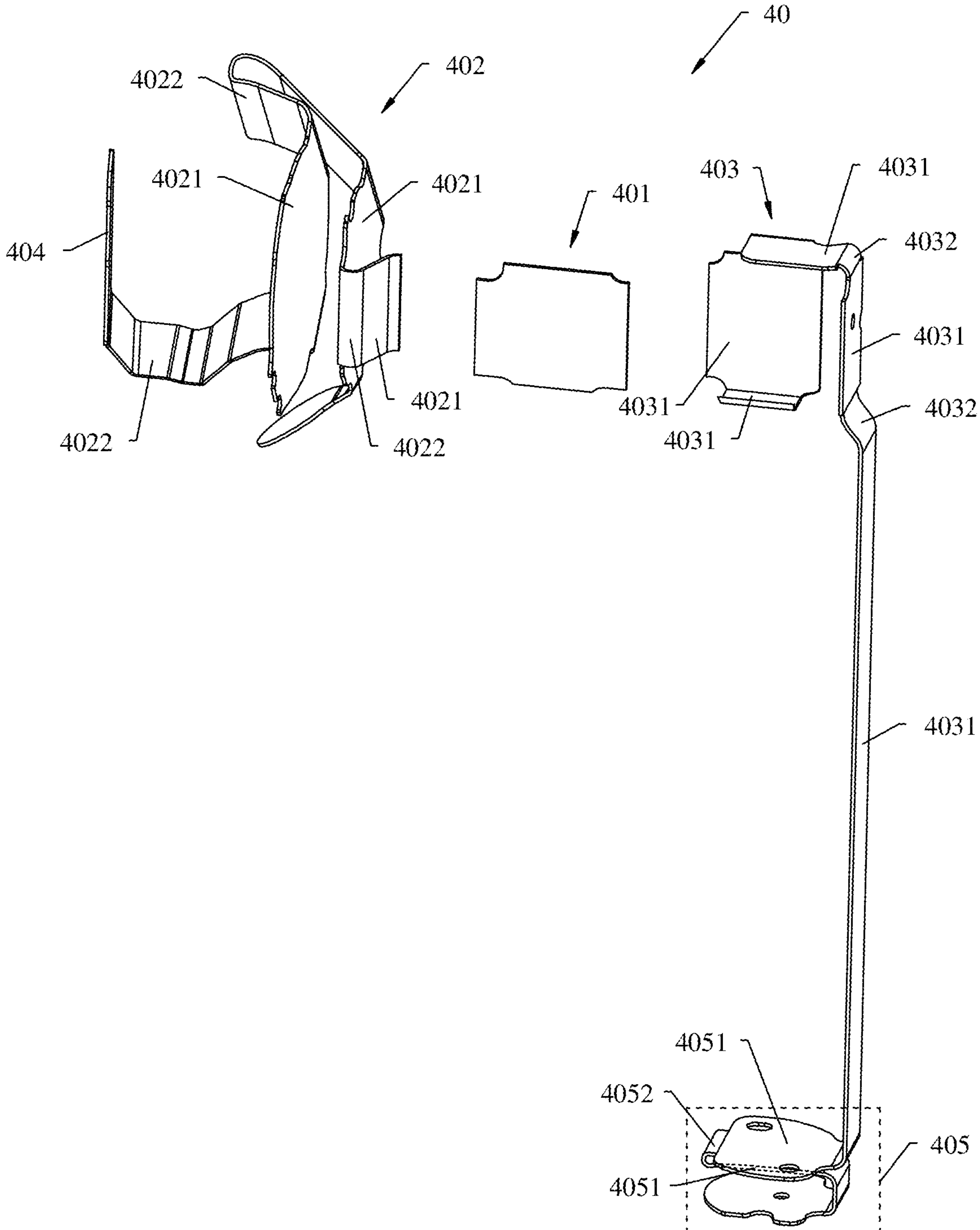
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FIG. 18

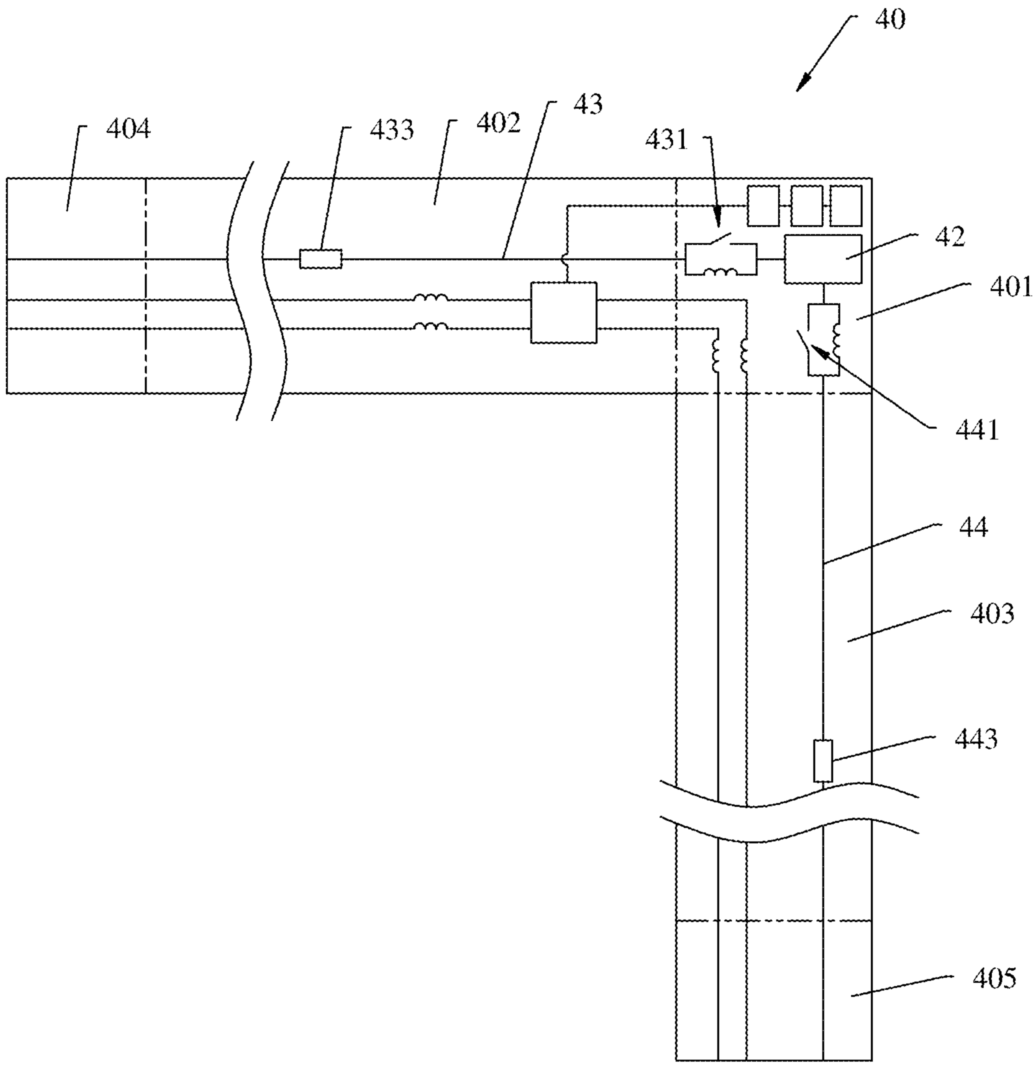

FIG. 19

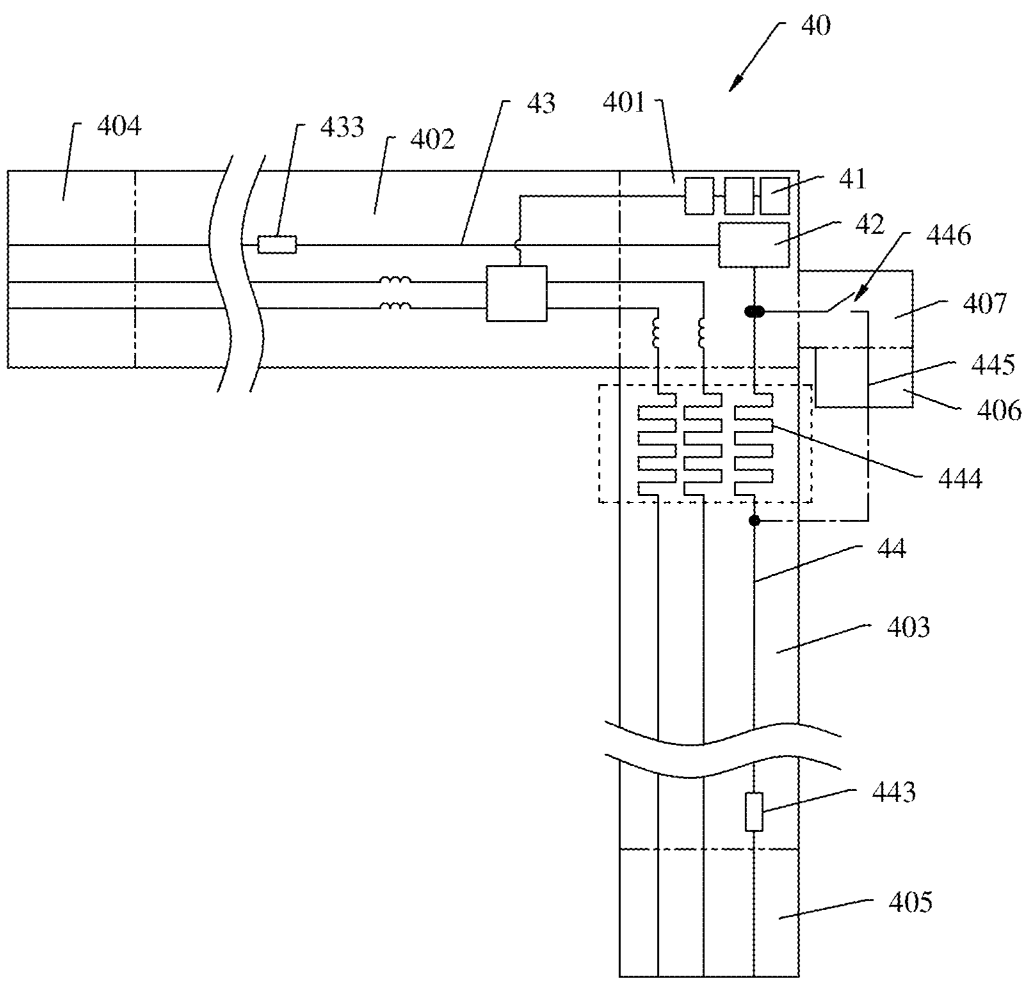

FIG. 20

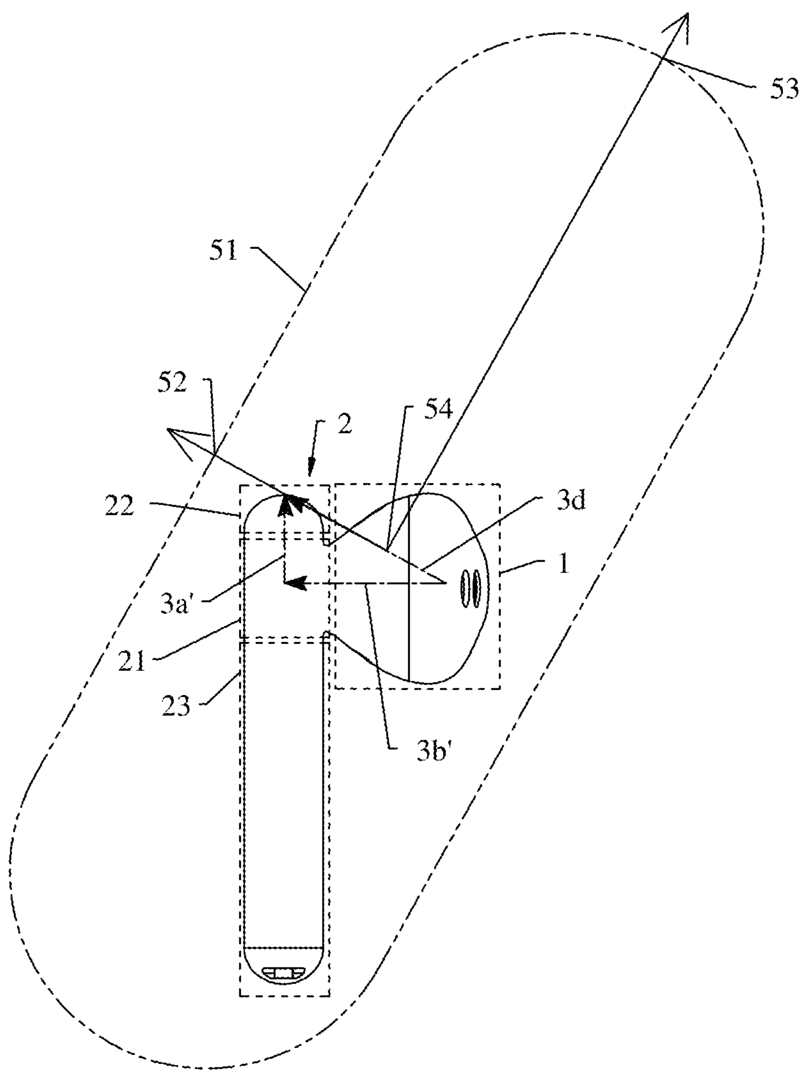

FIG. 21

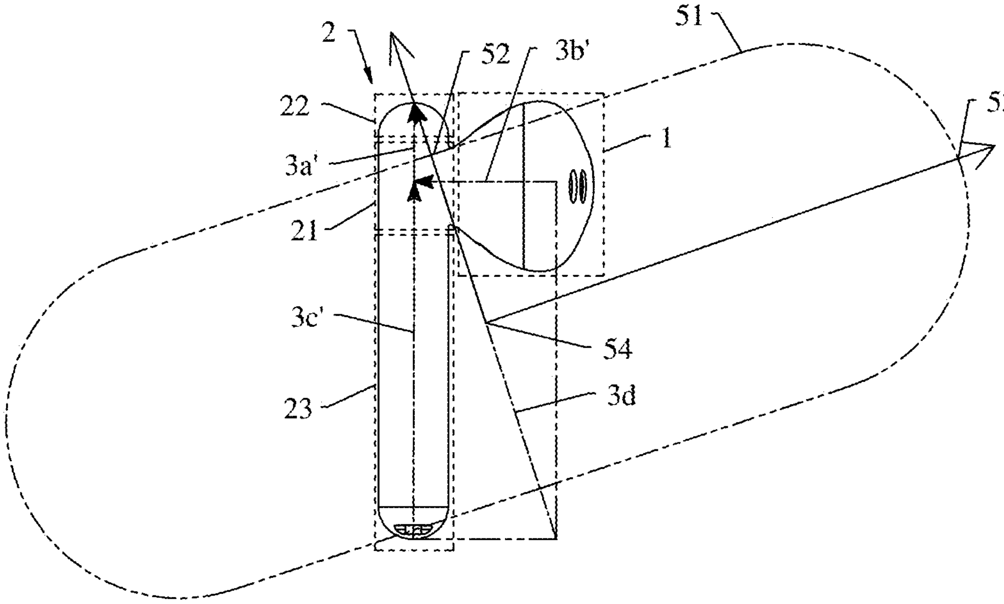

FIG. 22

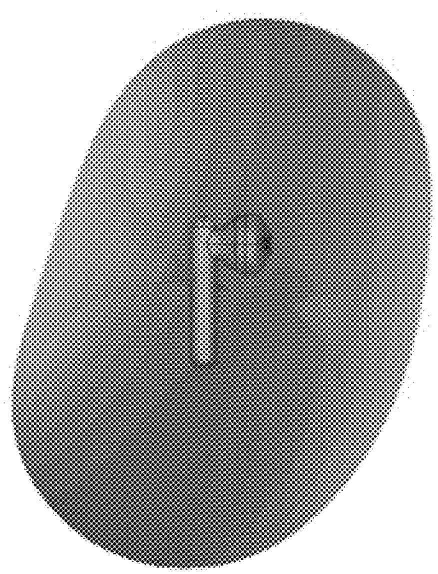

FIG. 23A

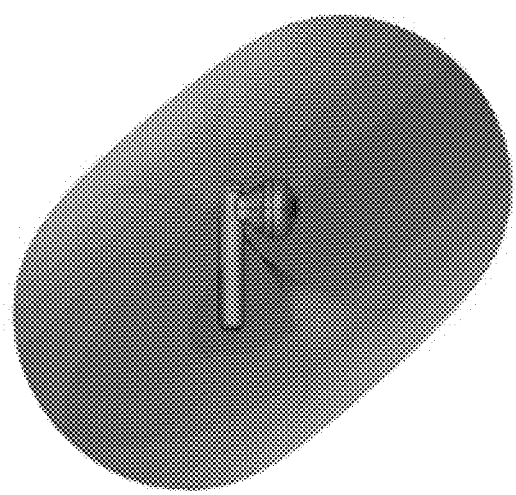

FIG. 23B

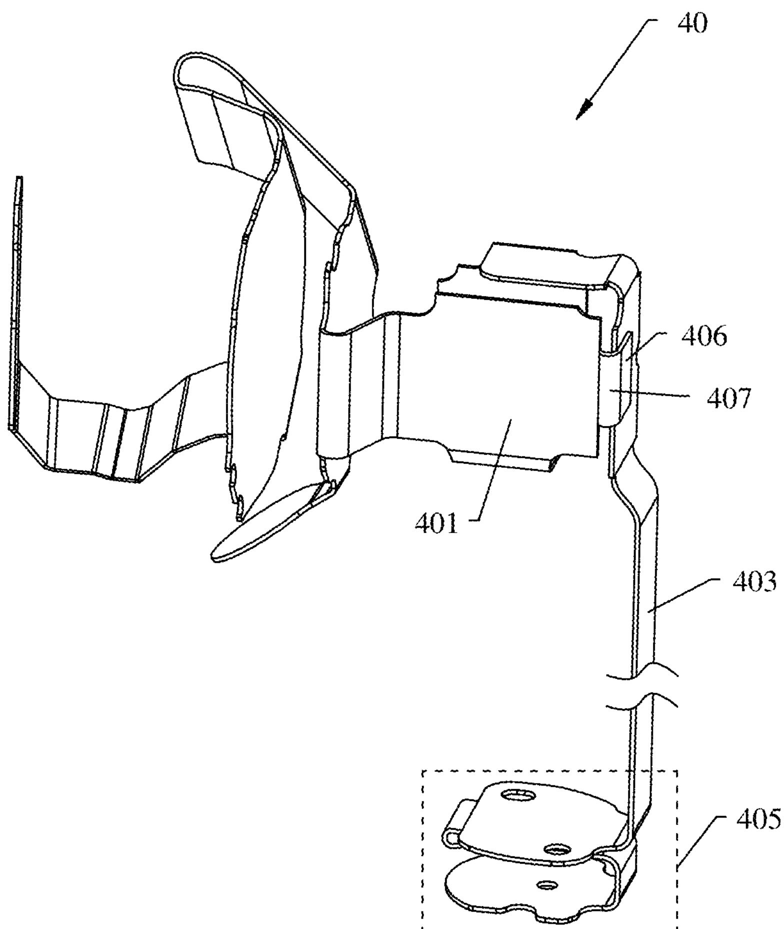

FIG. 24

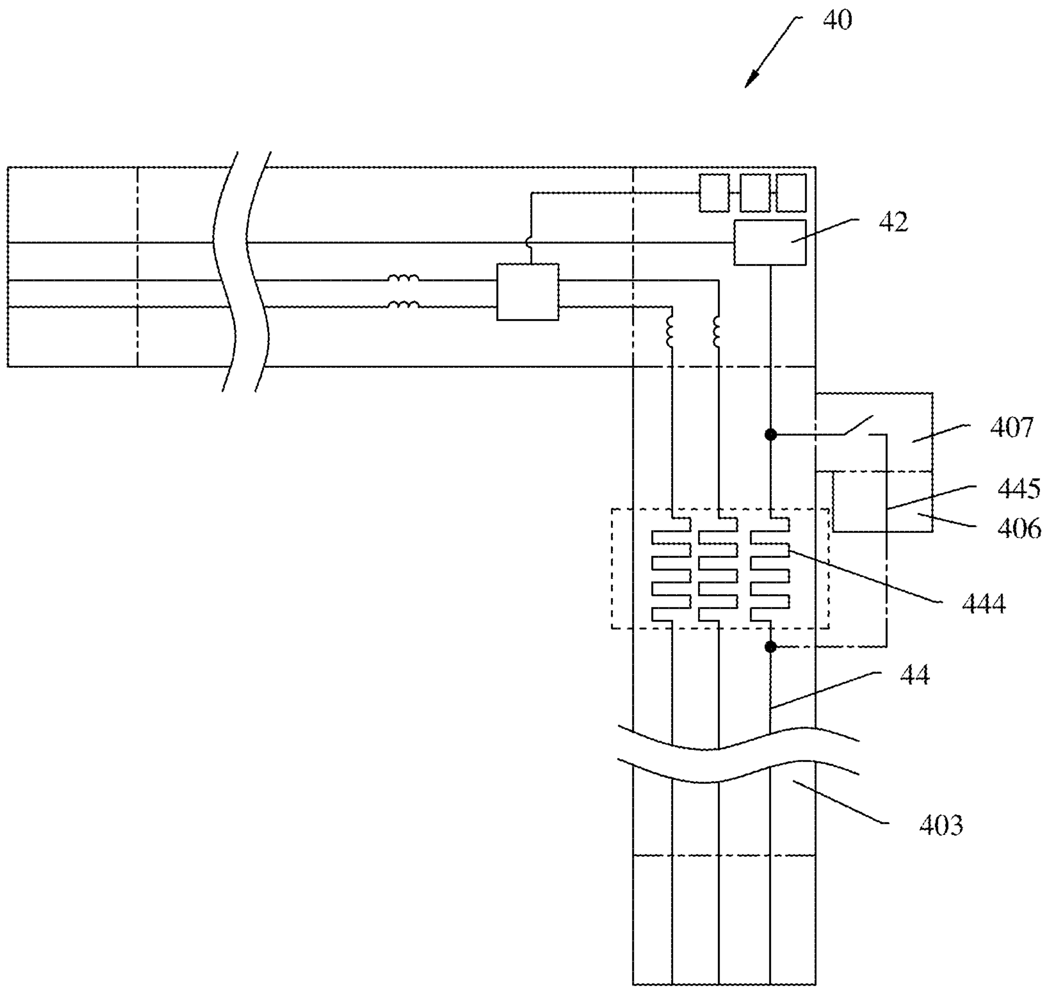

FIG. 25

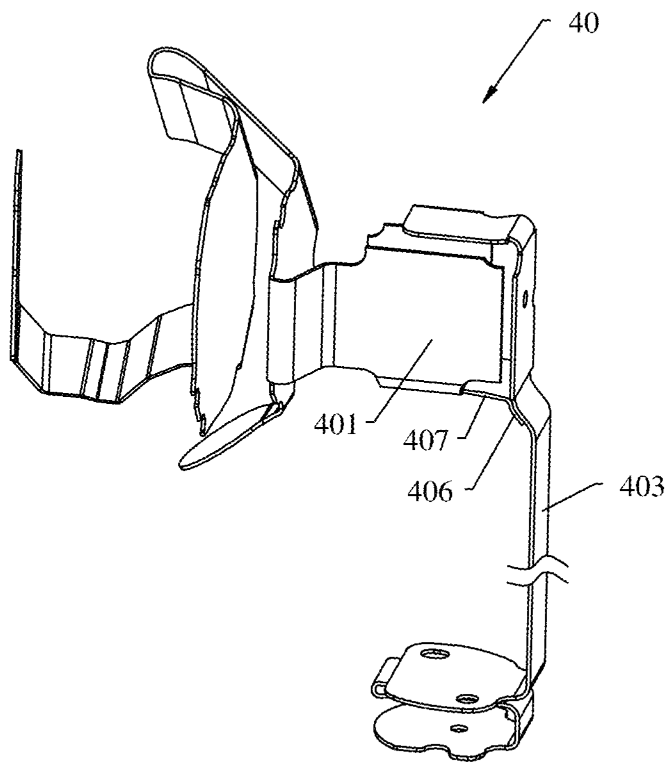

FIG. 26

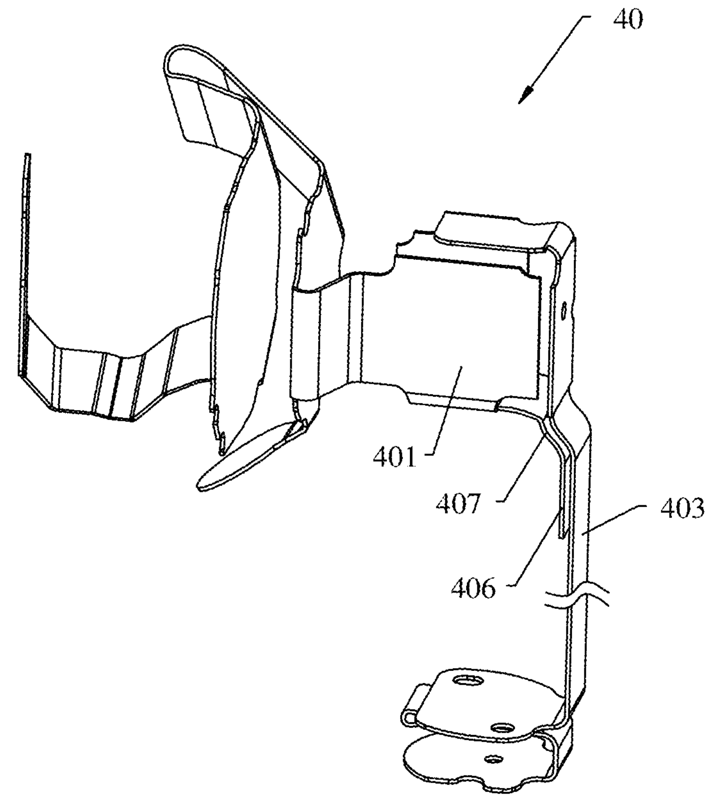

FIG. 27

BLUETOOTH EARPHONE

This application is a National Stage of International Patent Application No. PCT/CN2020/120866, filed on Oct. 14, 2020, which claims priority to Chinese Patent Application No. 201911056997.1, filed on Oct. 31, 2019, both of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

Embodiments relate to the field of bluetooth device technologies, and in particular, to a bluetooth earphone.

BACKGROUND

Currently, only one bluetooth antenna is usually disposed on a bluetooth earphone and the antenna has an obviously low antenna gain in some directions. When the antenna transmits and receives a signal in these low-antenna-gain directions, signal quality worsens and communication experience deteriorates.

SUMMARY

Embodiments provide a bluetooth earphone, and antenna gains of an antenna of the bluetooth earphone in all directions are relatively even.

According to a first aspect, an embodiment provides a bluetooth earphone. The bluetooth earphone has an earbud part and an earphone handle part. The earbud part is provided with an earpiece module. The earphone handle part includes a connecting section connected to the earbud part, and a top section and a bottom section located at both sides of the connecting section. The bottom section of the earphone handle part is provided with a first microphone module.

The bluetooth earphone includes an antenna and a circuit board. The antenna extends from the connecting section of the earphone handle part to the top section of the earphone handle part. The circuit board has a feeding part, a first end part, a first connection part, a second end part, and a second connection part. The feeding part is located at the connecting section of the earphone handle part. The first end part is located at the earbud part. The first connection part connects the feeding part and the first end part. The second end part is located at the bottom section of the earphone handle part. The second connection part connects the feeding part and the second end part.

The circuit board includes a feeding pad, a ground plane, a first grounding branch, and a second grounding branch. The feeding pad is located at the feeding part and coupled to the antenna. The ground plane is located at the feeding part and spaced from the feeding pad. The ground plane is grounded and serves as a part of a current return path of the antenna.

One end of the first grounding branch is connected to the ground plane and the other end extends to the first end part. The first grounding branch is connected in series to a first switch. When the first switch is on, the first grounding branch is configured to form a ground current, and the first grounding branch serves as a part of a current return path of the antenna. When the first switch is off, the first switch cuts off a current on the first grounding branch, and the first grounding branch does not provide an effective current return path for the antenna.

One end of the second grounding branch is connected to the ground plane and the other end extends to the second end part. The second grounding branch is connected in series to a second switch. When the second switch is on, the second grounding branch is configured to form a ground current, and the second grounding branch serves as a part of a current return path of the antenna. When the second switch is off, the second switch cuts off a current on the second grounding branch, and the second grounding branch does not provide an effective current return path for the antenna.

In this embodiment, the bluetooth earphone may form a plurality of ground structures by controlling states (on or off) of the first switch and the second switch, and select different grounding branches, in other words, select different current return paths, for the antenna by switching the ground structures, to switch radiation patterns of the antenna. The radiation patterns of the antenna in the plurality of ground structures are complementary. Therefore, the antenna has no obvious null in each radiation direction, and antenna gains of the antenna in all directions are relatively even, thereby improving communication quality and resolving a problem of poor communication experience caused by low gains of the antenna at some angles.

In an optional embodiment, the ground plane and the feeding pad are located at different conductive layers of the circuit board to form a gap therebetween. For example, the feeding pad is located at a surface conductive layer of the circuit board, and the ground plane is located at an inner conductive layer or another surface conductive layer of the circuit board. In some other embodiments, the ground plane and the feeding pad may be located at a same layer and form a gap therebetween, so as not to touch each other.

In an optional embodiment, the first connection part and the second connection part are connected to two sides of the feeding part. One side of the feeding part that is connected to the first connection part and another side of the feeding part that is connected to the second connection part may be disposed adjacently or oppositely. In this case, the circuit board can be well arranged inside the bluetooth earphone according to a shape of the bluetooth earphone.

In an optional embodiment, the antenna is configured to form a first current. The first current is an antenna current. The antenna includes a feeding end and an end away from the feeding end. The feeding end is connected to the feeding pad by using a conductive member to be coupled to the feeding part. The first current extends from the feeding end to the end and a direction of the first current is from the connecting section of the earphone handle part to the top section of the earphone handle part. The antenna may be a quarter-wavelength antenna, to have relatively high antenna efficiency. An electrical length of the antenna may be implemented by adjusting a physical length of the antenna.

When the first switch is on and the second switch is off, the first grounding branch is configured to form a second current. The second current and the first current are capable of composing into an equivalent current in resonant mode. The first grounding branch serves as a current return path. The second current is a ground current. The second current extends from an end of the first grounding branch that is away from the ground plane to the ground plane. The second current extends from a first end part of the circuit board to the feeding part, and a direction of the second current is from the earbud part to the connecting section of the earphone handle part. When the first switch is on, an electrical length of the first grounding branch is or is close to a quarter wavelength, so that the second current is in resonant mode and effective radiation can be formed. When an electrical length of the first current is a quarter wavelength and an electrical length of the second current is a quarter wavelength, an electrical length of an equivalent current composed by the first current and the second current is a half wavelength, and the equivalent current is in resonant mode, so that an antenna signal is effectively radiated. The equivalent current extends from the earbud part to the top section of the earphone handle part.

In this embodiment, because the direction of the first current is from the connecting section of the earphone handle part to the top section of the earphone handle part, and the direction of the second current is from the earbud part to the connecting section of the earphone handle part, the direction of the equivalent current composed by the first current and the second current is from the earbud part to the top section of the earphone handle part. Therefore, when a user wears the bluetooth earphone, a radiation null of a radiation field pattern of the antenna of the bluetooth earphone is toward the user head, thereby greatly reducing an adverse effect of the user head to the antenna and enabling the antenna to have better antenna performance.

When the second switch is on and the first switch is off, the second grounding branch is configured to form a third current. The third current and the first current are capable of composing into an equivalent current in resonant mode. The second grounding branch serves as a current return path. The third current is a ground current. The third current extends from an end of the second grounding branch that is away from the ground plane to the ground plane. The third current extends from a second end part of the circuit board to the feeding part, and a direction of the third current is from the bottom section of the earphone handle part to the connecting section of the earphone handle part. When the second switch is on, an electrical length of the second grounding branch is or is close to a quarter wavelength, so that the third current is in resonant mode and effective radiation can be formed. When an electrical length of the first current is a quarter wavelength and an electrical length of the third current is a quarter wavelength, an electrical length of an equivalent current composed by the first current and the third current is a half wavelength, and the equivalent current is in resonant mode. The equivalent current extends from the bottom section of the earphone handle part to the top section of the earphone handle part.

In an optional embodiment, when the first switch is on and the second switch is on, the first grounding branch is configured to form a second current, and the second grounding branch is configured to form a third current. The first current, the second current, and the third current are capable of composing into an equivalent current in resonant mode. The first grounding branch and the second grounding branch serve as current return paths. When an electrical length of the first current is a quarter wavelength, an electrical length of the second current is a quarter wavelength, and an electrical length of the third current is a quarter wavelength, an electrical length of an equivalent current composed by the first current, the second current, and the third current is a three-quarter wavelength, and the equivalent current is in resonant mode, so that an antenna signal is effectively radiated. The equivalent current extends from the underside of the earbud part (namely, the side near the bottom section of the earphone handle part) to the top section of the earphone handle part.

In an optional embodiment, the first switch is located at the feeding part, or is located at an end of the first connection part that is close to the feeding part. In this case, an electrical length of a part of the first grounding branch that is located between the first switch and the ground plane is less than a quarter wavelength, a current on the part is not in resonant mode, and effective radiation cannot be formed. It may be understood that, in some other embodiments, the first switch may be located elsewhere, provided that the electrical length of the part of the first grounding branch that is located between the first switch and the ground plane is not equal to N/4 wavelengths, where N is a positive integer.

The second switch is located at the feeding part or at an end of the second connection part that is close to the feeding part. In this case, an electrical length of a part of the first grounding branch that is located between the first switch and the ground plane is less than a quarter wavelength, a current on the part is not in resonant mode, and effective radiation cannot be formed. It may be understood that, in some other embodiments, the second switch may be located elsewhere, provided that the electrical length of the part of the first grounding branch that is located between the first switch and the ground plane is not equal to N/4 wavelengths, where N is a positive integer.

In an optional embodiment, the first grounding branch is further connected in series to a first choke inductor, and the first choke inductor is disposed in parallel with the first switch. In this embodiment, the first grounding branch is not only configured to provide a current return path for the antenna, but also configured to provide a reference ground for another functional module of the bluetooth earphone. Because the first choke inductor is disposed in parallel with the first switch, and the first choke inductor is connected in series to the first grounding branch, the first grounding branch as a reference ground for a low frequency signal is continuous and complete. For example, the earpiece module is connected to the first grounding branch. The first grounding branch is further configured to provide a reference ground for the earpiece module. For example, an inductance value of the first choke inductor may be greater than or equal to 22 nanohenries (nH) to block a signal in the bluetooth frequency band (2.4 GHz) and allow passage of a low frequency signal that is below the bluetooth frequency band.

In an optional embodiment, the second grounding branch is further connected in series to a second choke inductor, and the second choke inductor is disposed in parallel with the second switch. In this embodiment, the second grounding branch is not only configured to provide a current return path for the antenna, but also configured to provide a reference ground for another functional module of the bluetooth earphone. Because the second choke inductor is disposed in parallel with the second switch, and the second choke inductor is connected in series to the second grounding branch, the second grounding branch as a reference ground for a low frequency signal is continuous and complete. For example, the first microphone module is connected to the second grounding branch. The second grounding branch is further configured to provide a reference ground for the first microphone module. For example, an inductance value of the second choke inductor may be greater than or equal to 22 nanohenries (nH) to block a signal in the bluetooth frequency band (2.4 GHz) and allow passage of a low frequency signal that is below the bluetooth frequency band.

In an optional embodiment, the bluetooth earphone further includes a chip. The chip is located at the earbud part and connected to the circuit board. The circuit board further includes a first low-frequency signal line and a second low-frequency signal line. One end of the first low-frequency signal line is connected to the chip and the other end extends to the first end part. The first low-frequency signal line is connected in series to a third choke inductor. One end of the second low-frequency signal line is connected to the chip and the other end extends to the second end part. The second low-frequency signal line is connected in series to a fourth choke inductor. The first low-frequency signal line and the second low-frequency signal line may be connected to another functional module of the bluetooth earphone and are configured to transmit a low-frequency signal between the functional module and the chip.

The earpiece module is connected to the first low-frequency signal line. The first low-frequency signal line transmits a signal between the earpiece module and the chip. Because some locations of the first low-frequency signal line may be capacitively coupled to the first grounding branch, the first low-frequency signal line is connected in series to the third choke inductor, and the first low-frequency signal line is isolated from the ground at a high frequency by using the third choke inductor.

The first microphone module is connected to the second low-frequency signal line. The first low-frequency signal line transmits a signal between the first microphone module and the chip. Because some locations of the second low-frequency signal line may be capacitively coupled to the second grounding branch, the second low-frequency signal line is connected in series to the fourth choke inductor, and the second low-frequency signal line is isolated from the ground at a high frequency by using the fourth choke inductor.

In an optional embodiment, the circuit board further includes a first power cable and a second power cable. One end of the first power cable is connected to the chip, and the other end of the first power cable extends to the first end part. One end of the second power cable is connected to the chip, and the other end of the second power cable extends to the second end part. The first power cable and the second power cable are connected to a power management module of the chip. The second power cable is connected to a battery, and the power management module is configured to control a charging/discharging process of the battery and a power supply process for another functional module. The first power cable and the second power cable are further configured to connect to another functional module of the bluetooth earphone, such as the earpiece module or the first microphone module, so that the battery can supply power to the functional module of the bluetooth earphone. A fifth choke inductor may be connected in series to the first power cable, and a sixth choke inductor may be connected in series to the second power cable.

In an optional embodiment, the first grounding branch is further connected in series to a first low-pass high-resistance element, and the first low-pass high-resistance element is disposed in series with the first switch and is located at a side of the first switch that is away from the ground plane. The first low-pass high-resistance element is configured to allow passage of a current whose frequency band is lower than the bluetooth signal frequency band and prevent passage of a current whose frequency band is close to the bluetooth signal frequency band. In this case, the first low-pass high-resistance element changes the electrical length of the first grounding branch as the current return path of the antenna, so that the first grounding branch meets the electrical length requirement, without affecting a function of the first grounding branch as a reference ground for a low frequency signal. For example, the first low-pass high-resistance element may be located at the first connection part or the first end part.

In an optional embodiment, the second grounding branch is further connected in series to a second low-pass high-resistance element, and the second low-pass high-resistance element is disposed in series with the second switch and is located at a side of the second switch that is away from the ground plane. The second low-pass high-resistance element is configured to allow passage of a current whose frequency band is lower than the bluetooth signal frequency band and prevent passage of a current whose frequency band is close to the bluetooth signal frequency band. In this case, the second low-pass high-resistance element changes the electrical length of the second grounding branch as the current return path of the antenna, so that the second grounding branch meets the electrical length requirement, without affecting a function of the second grounding branch as a reference ground for a low frequency signal. For example, the second low-pass high-resistance element may be located at the second connection part or the second end part.

In an optional embodiment, the first connection part includes a plurality of sequentially connected regions, and the plurality of regions include one or more flat regions and one or more bent regions. The length of the first connection part may be effectively adjusted in a manner of bending or stretching by increasing or decreasing a quantity or area of the flat regions and the bent regions, to adjust the length of the first grounding branch, so that the electrical length of the first grounding branch meets a requirement.

In an optional embodiment, the second connection part includes a plurality of sequentially connected regions, and the plurality of regions include one or more flat regions and one or more bent regions. The length of the second connection part may be effectively adjusted in a manner of bending or stretching by increasing or decreasing a quantity or area of the flat regions and the bent regions, to adjust the length of the second grounding branch, so that the electrical length of the second grounding branch meets a requirement.

In an optional embodiment, the second end part includes a plurality of sequentially connected regions, and the plurality of regions include one or more flat regions and one or more bent regions. The length of the second end part may be effectively adjusted in a manner of bending or stretching by increasing or decreasing a quantity or area of the flat regions and the bent regions, to adjust the length of the second grounding branch, so that the electrical length of the second grounding branch meets a requirement.

According to a second aspect, an embodiment further provides a bluetooth earphone. The bluetooth earphone has an earbud part and an earphone handle part. The earbud part is provided with an earpiece module. The earphone handle part includes a connecting section connected to the earbud part, and a top section and a bottom section located at both sides of the connecting section. The bottom section of the earphone handle part is provided with a first microphone module.

The bluetooth earphone includes an antenna and a circuit board. The antenna extends from the connecting section of the earphone handle part to the top section of the earphone handle part. The circuit board has a feeding part, a first end part, a first connection part, a second end part, and a second connection part. The feeding part is located at the connecting section of the earphone handle part. The first end part is located at the earbud part. The first connection part connects the feeding part and the first end part. The second end part is located at the bottom section of the earphone handle part. The second connection part connects the feeding part and the second end part.

The circuit board includes a feeding pad, a ground plane, a first grounding branch, and a second grounding branch. The feeding pad is located at the feeding part and coupled to the antenna. The ground plane is located at the feeding part and spaced from the feeding pad. One end of the first grounding branch is connected to the ground plane and the other end extends to the first end part. One end of the second grounding branch is connected to the ground plane and the other end extends to the second end part.

The second grounding branch is connected in series to a first branch. The second grounding branch further includes a second branch. One end of the second branch is connected to one end of the first branch, and the other end of the second branch is connected or coupled to the other end of the first branch. The second branch is connected in series to a switch. The second branch is shorter than the first branch.

In this embodiment, because a part that is of the second connection part of the circuit board and that is close to the feeding part is located at the connecting section of the earphone handle part of the bluetooth earphone, the second connection part needs to be folded inevitably. Therefore, the second connection part is relatively long, and the second grounding branch passing the second connection part and extending to the second end part is also relatively long. Because the second branch is disposed in parallel with the first branch, and the second branch is shorter than the first branch, when a switch of the second branch is off, a third current on the second grounding branch selects the longer first branch as a path, an electrical length of the second grounding branch is greater than a quarter wavelength, and effective radiation is difficult to form. Therefore, a current return path of the antenna is the first grounding branch. When the switch of the second branch is on, the third current on the second grounding branch selects the shorter second branch as a path, an electrical length of the second grounding branch can be shortened to a quarter wavelength to perform effective radiation, and both the second grounding branch and the first grounding branch serve as current return paths of the antenna.

In an optional embodiment, the antenna is configured to form a first current. The first current is an antenna current. A flow direction of the first current varies with a shape direction of the antenna. The antenna includes a feeding end and an end away from the feeding end. The feeding end is connected to the feeding pad by using a conductive member to be coupled to the feeding part. The first current extends from the feeding end to the end a direction of the first current is from the connecting section of the earphone handle part to the top section of the earphone handle part. The antenna may be a quarter-wavelength antenna, to have relatively high antenna efficiency. An electrical length of the antenna may be implemented by adjusting a physical length of the antenna.

When the switch is off, the first grounding branch is configured to form a second current, and the second current and the first current are capable of composing into an equivalent current in resonant mode. When the switch is off, the first grounding branch serves as a current return path of the antenna. When an electrical length of the first current is a quarter wavelength and an electrical length of the second current is a quarter wavelength, an electrical length of an equivalent current composed by the first current and the second current is a half wavelength, and the equivalent current is in resonant mode, so that an antenna signal is effectively radiated. The equivalent current extends from the earbud part to the top section of the earphone handle part.

In this embodiment, because the direction of the first current is from the connecting section of the earphone handle part to the top section of the earphone handle part, and the direction of the second current is from the earbud part to the connecting section of the earphone handle part, the direction of the equivalent current composed by the first current and the second current is from the earbud part to the top section of the earphone handle part. Therefore, when a user wears the bluetooth earphone, a radiation null of a radiation field pattern of the antenna of the bluetooth earphone is toward the user head, thereby greatly reducing an adverse effect of the user head to the antenna and enabling the antenna to have better antenna performance.

When the switch is on, the first grounding branch is configured to form a second current, the second grounding branch is configured to form a third current, and the first current, the second current, and the third current are capable of composing into an equivalent current in resonant mode. When the switch is on, the first grounding branch and the second grounding branch serve as current return paths. When an electrical length of the first current is a quarter wavelength, an electrical length of the second current is a quarter wavelength, and an electrical length of the third current is a quarter wavelength, an electrical length of an equivalent current composed by the first current, the second current, and the third current is a three-quarter wavelength, and the equivalent current is in resonant mode, so that an antenna signal is effectively radiated. The equivalent current extends from the underside of the earbud part (namely, the side near the bottom section of the earphone handle part) to the top section of the earphone handle part.

In an optional embodiment, the circuit board further includes a third end part and a third connection part. The third end part is located at the connecting section of the earphone handle part or at an end of the bottom section of the earphone handle part that is close to the connecting section of the earphone handle part, and the third end part is connected to or close to the second connection part. When the third end part is connected (for example, welded or connected by conductive adhesive) to the second connection part, an electrical connection is formed therebetween. That the third end part is disposed close to the second connection part means that the third end part touches the second connection part, or that the third end part does not touch the second connection part, but a small gap exists therebetween, and electrical coupling is formed between the third end part and the second connection part. One end of the third connection part is connected to the third end part and the other end is connected to the feeding part or the first connection part. One end of the second branch that is away from the ground plane extends to the third end part by using the third connection part.

In this embodiment, the second branch located at the third connection part and the third end part can effectively shorten an electrical length of the second grounding branch, to meet an electrical length requirement.

In an optional embodiment, the earpiece module is connected to the first grounding branch. The first grounding branch may serve as a current return path of the antenna and may also serve as a reference ground for a low frequency signal of the earpiece module. The first microphone module is connected to the second grounding branch. The second grounding branch may serve as a current return path of the antenna and may also serve as a reference ground for a low frequency signal of the first microphone module.

In an optional embodiment, the first grounding branch is connected in series to a first low-pass high-resistance element. The second grounding branch is connected in series to a second low-pass high-resistance element, and the second low-pass high-resistance element is disposed in series with the first branch and is located at a side of the first branch that is away from the ground plane. The first low-pass high-resistance element and the second low-pass high-resistance element are configured to allow passage of a current whose frequency band is lower than a bluetooth signal frequency band and prevent passage of a current whose frequency band is close to the bluetooth signal frequency band.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic diagram of a structure of a bluetooth earphone according to an embodiment;

FIG. **2** is a partial exploded schematic diagram of the bluetooth earphone shown in FIG. **1**;

FIG. **3** is a schematic diagram of an internal structure of the bluetooth earphone shown in FIG. **1**;

FIG. **4** is a schematic diagram of a structure of a circuit board shown in FIG. **2** in an embodiment;

FIG. **5** is a schematic current diagram of a partial structure of the bluetooth earphone shown in FIG. **3**;

FIG. **6** is a schematic diagram of a partial structure of a feeding part of the circuit board shown in FIG. **4** in some embodiments;

FIG. **7** is a schematic diagram of an equivalent current of the structure shown in FIG. **5**;

FIG. **8** is a schematic diagram of a radiation field pattern of the bluetooth earphone shown in FIG. **1** in a first ground structure of the circuit board shown in FIG. **4**;

FIG. **9** is a schematic diagram of a radiation field pattern of the bluetooth earphone shown in FIG. **1** in a second ground structure of the circuit board shown in FIG. **4**;

FIG. **10** is a schematic diagram of a radiation field pattern of the bluetooth earphone shown in FIG. **1** in a third ground structure of the circuit board shown in FIG. **4**;

FIG. **11**A is a simulation diagram of a radiation field pattern of a bluetooth earphone when the circuit board shown in FIG. **4** is switched to a first ground structure;

FIG. **11**B is a simulation diagram of a radiation field pattern of a bluetooth earphone when the circuit board shown in FIG. **4** is switched to a second ground structure;

FIG. **11**C is a simulation diagram of a radiation field pattern of a bluetooth earphone when the circuit board shown in FIG. **4** is switched to a third ground structure;

FIG. **12** is a comparison radiation pattern of a vertical section of the bluetooth earphone shown in FIG. **1** in free space in a plurality of ground structures of the circuit board shown in FIG. **4**;

FIG. **13**A is a simulation diagram of a radiation field pattern of a bluetooth earphone corresponding to a head mode in free space when the circuit board shown in FIG. **4** is switched to a first ground structure;

FIG. **13**B is a simulation diagram of a radiation field pattern of a bluetooth earphone corresponding to a head mode in free space when the circuit board shown in FIG. **4** is switched to a second ground structure;

FIG. **13**C is a simulation diagram of a radiation field pattern of a bluetooth earphone corresponding to a head mode in free space when the circuit board shown in FIG. **4** is switched to a third ground structure;

FIG. **14**A is a simulation diagram of a radiation field pattern of a bluetooth earphone corresponding to a head mode when the circuit board shown in FIG. **4** is switched to a first ground structure;

FIG. **14**B is a simulation diagram of a radiation field pattern of a bluetooth earphone corresponding to a head mode when the circuit board shown in FIG. **4** is switched to a second ground structure;

FIG. **14**C is a simulation diagram of a radiation field pattern of a bluetooth earphone corresponding to a head mode when the circuit board shown in FIG. **4** is switched to a third ground structure;

FIG. **15**A is a comparison radiation pattern of the bluetooth earphone shown in FIG. **1** corresponding to a vertical section of a head mode in a plurality of ground structures of the circuit board shown in FIG. **4**;

FIG. **15**B is a comparison radiation pattern of the bluetooth earphone shown in FIG. **1** corresponding to a horizontal section of a head mode in a plurality of ground structures of the circuit board shown in FIG. **4**;

FIG. **16** is a schematic diagram of the bluetooth earphone shown in FIG. **1** in a use state;

FIG. **17** is a schematic diagram of a structure of the circuit board shown in FIG. **2** in another embodiment;

FIG. **18** is a schematic diagram of a structure of the circuit board shown in FIG. **4** in a first implementation;

FIG. **19** is a schematic diagram of a structure of the circuit board shown in FIG. **4** in a second implementation;

FIG. **20** is a schematic diagram of a structure of the circuit board shown in FIG. **2** in still another embodiment;

FIG. **21** is a schematic diagram of a radiation field pattern of the bluetooth earphone shown in FIG. **1** in a first ground structure of the circuit board shown in FIG. **20**;

FIG. **22** is a schematic diagram of a radiation field pattern of the bluetooth earphone shown in FIG. **1** in a second ground structure of the circuit board shown in FIG. **20**;

FIG. **23**A is a simulation diagram of a radiation field pattern of a bluetooth earphone when the circuit board shown in FIG. **20** is switched to a first ground structure;

FIG. **23**B is a simulation diagram of a radiation field pattern of a bluetooth earphone when the circuit board shown in FIG. **20** is switched to a second ground structure;

FIG. **24** is a schematic diagram of a structure of the circuit board shown in FIG. **20** in some embodiments;

FIG. **25** is a schematic diagram of a structure of the circuit board shown in FIG. **2** in still another embodiment;

FIG. **26** is a schematic diagram of a structure of the circuit board shown in FIG. **25** in some embodiments; and

FIG. **27** is a schematic diagram of a structure of the circuit board shown in FIG. **25** in some other embodiments.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The following describes embodiments with reference to the accompanying drawings.

A bluetooth earphone in the embodiments has a plurality of ground structures. Different current return paths are selected for the antenna by switching the ground structures, to switch radiation patterns of the antenna. The radiation patterns of the antenna in the plurality of ground structures are complementary. Therefore, the antenna has no obvious null in each radiation direction, and antenna gains of the antenna in all directions are relatively even, thereby improving communication quality and resolving a problem of poor communication experience caused by low gains of the antenna at some angles.

FIG. **1** is a schematic diagram of a structure of a bluetooth earphone **100** according to an embodiment.

The bluetooth earphone **100** has an earbud part **1** and an earphone handle part **2**. The earphone handle part **2** includes a connecting section **21** connected to the earbud part **1**, and a top section **22** and a bottom section **23** located at both sides of the connecting section **21**. The top section **22**, the connecting section **21**, and the bottom section **23** of the earphone handle part **2** are arranged sequentially. The earbud part **1** is configured to be partially inserted into a user ear. The earphone handle part **2** is configured to touch the user ear. When a user wears the bluetooth earphone **100**, the earbud part **1** is partially inserted in the user ear, and the earphone handle part **2** is located outside the user ear and touches the user ear.

FIG. **2** is a partial exploded schematic diagram of the bluetooth earphone **100** shown in FIG. **1**. The bluetooth earphone **100** includes a housing **10**. The housing **10** is configured to accommodate other components of the bluetooth earphone **100**, to fasten and protect the other components. The housing **10** includes a main housing **101**, a bottom housing **102**, and a side housing **103**. The main housing **101** is partially disposed on the earphone handle part **2** of the bluetooth earphone **100**, and partially disposed on the earbud part **1** of the bluetooth earphone **100**. The main housing **101** is provided with a first opening **1011** at the bottom section **23** of the earphone handle part **2** of the bluetooth earphone **100**, and a second opening **1012** at the earbud part **1** of the bluetooth earphone **100**. Another component of the bluetooth earphone **100** may be installed into the main housing **101** through the first opening **1011** or the second opening **1012**. The bottom housing **102** is located at the bottom section **23** of the earphone handle part **2** of the bluetooth earphone **100** and fixedly connected to the main housing **101**. The bottom housing **102** is mounted to the first opening **1011**. The side housing **103** is located at the earbud part **1** of the bluetooth earphone **100** and fixedly connected to the main housing **101**. The side housing **103** is mounted to the second opening **1012**.

The connection between the bottom housing **102** and the main housing **101** is a detachable connection (for example, a snap-fit connection or a threaded connection), to facilitate subsequent fix or maintenance of the bluetooth earphone **100**. In another implementation, the connection between the bottom housing **102** and the main housing **101** may be a non-detachable connection (for example, a glue connection), to reduce a risk of accidental falling off of the bottom housing **102** and make the bluetooth earphone **100** more reliable.

The connection between the side housing **103** and the main housing **101** is a detachable connection (for example, a snap-fit connection or a threaded connection), to facilitate subsequent fix or maintenance of the bluetooth earphone **100**. In another embodiment, the connection between the side housing **103** and the main housing **101** may be a non-detachable connection (for example, a glue connection), to reduce a risk of accidental falling off of the side housing **103** and make the bluetooth earphone **100** more reliable.

The side housing **103** is provided with one or more sound outlets **1031**, so that sound inside the housing **10** can be transmitted to the outside of the housing **10** through the sound outlet **1031**. A shape, a location, a quantity, and the like of the sound outlet **1031** are not strictly limited.

FIG. **3** is a schematic diagram of an internal structure of the bluetooth earphone **100** shown in FIG. **1**.

The bluetooth earphone **100** further includes an antenna **20**, an antenna holder **30**, a circuit board **40**, a chip **50**, an earpiece module **60**, a battery **70**, a conductive member **80**, a first microphone module **90**, and a second microphone module **110**.

The antenna **20** extends from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**. Optionally, the antenna **20** may be a monopole antenna, an inverted F-shaped antenna (IFA), or the like. Optionally, the antenna **20** may be a ceramic antenna, a circuit board antenna, a steel sheet antenna, a laser direct structuring (LDS) antenna, an in-mold injection molding antenna, or the like. In this embodiment, an example in which the antenna **20** is a laser direct structuring antenna is used for description.

The antenna holder **30** extends from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**. The antenna holder **30** is configured to fasten and support the antenna **20**. In this embodiment, the antenna **20** is formed on the antenna holder **30**. For example, the antenna **20** is formed on the antenna holder **30** after a coating process and a baking process that are alternately performed for a plurality of cycles. In one example, the antenna **20** is formed by alternating three coating processes and three baking processes to improve a product yield. In another embodiment, the antenna **20** may be fastened to the antenna holder **30** in an assembly manner. For example, the antenna **20** is welded or bonded to the antenna holder **30**.

For example, a material of the antenna holder **30** may be ceramic. In this case, a relatively high dielectric constant of the ceramic can effectively reduce the size of the antenna **20**. In another embodiment, the material of the antenna holder **30** may be plastic.

In some embodiments, as shown in FIG. **2** and FIG. **3**, the circuit board **40** extends from the earbud part **1**, through the connecting section **21** of the earphone handle part **2**, to the bottom section **23** of the earphone handle part **2**. The circuit board **40** may form one or more bent structures at the earbud part **1** and the earphone handle part **2**. The circuit board **40** is configured to transmit a signal. The circuit board **40** may be an integrally formed flexible printed circuit (FPC) board, or an integrally formed soft-hard-composed circuit board, or an integral structure formed by connecting a plurality of flexible printed circuit boards to each other, or an integral structure formed by connecting one or more flexible printed circuit boards and one or more hard circuit boards. A type of the circuit board **40** is not strictly limited.

For example, the circuit board **40** includes a feeding part **401**, a first connection part **402**, a second connection part **403**, a first end part **404**, and a second end part **405**. The feeding part **401** is located at the connecting section **21** of the earphone handle part **2**. The first end part **404** and the second end part **405** are two end parts of the circuit board **40**. The first end part **404** is located at the earbud part **1**. The second end part **405** is located at the bottom section **23** of the earphone handle part **2**. The first connection part **402** connects the feeding part **401** and the first end part **404**. The first connection part **402** extends to the earbud part **1**. A large part of the first connection part **402** is located at the earbud part **1**, and a small part is located at the earphone handle part **2**; or the first connection part **402** is not located at the earphone handle part **2**. The second connection part **403** connects the feeding part **401** and the second end part **405**. The second connection part **403** extends from the connecting section **21** of the earphone handle part **2** to the bottom section **23** of the earphone handle part **2**.

In this embodiment, the first connection part **402** and the second connection part **403** are connected to two sides of the feeding part **401** respectively. One side of the feeding part **401** that is connected to the first connection part **402** and another side of the feeding part **401** that is connected to the second connection part **403** may be disposed adjacently or oppositely. In this case, the circuit board **40** can be well arranged inside the bluetooth earphone **100** according to a shape of the bluetooth earphone **100**.

For example, the circuit board **40** may include one or more reinforcing plates (not shown in the figure). The one or more reinforcing plates are provided at a reinforcing region of the circuit board **40**. The reinforcing region of the circuit board **40** is a region in the circuit board **40** that needs to be connected to another component, or a region configured to carry another component.

In some embodiments, as shown in FIG. **2** and FIG. **3**, the conductive member **80** is located at the connecting section **21** of the earphone handle part **2**. The conductive member **80** is fastened to the feeding part **401** of the circuit board **40** and configured to connect to the antenna **20** located at the antenna holder **30**. For example, the conductive member **80** may be a conductive spring. In another embodiment, the conductive member **80** may be another structure, such as conductive adhesive. In another embodiment, the conductive member **80** may be replaced by a capacitor, and the feeding part **401** is coupled to the antenna **20** by the capacitor.

In some embodiments, as shown in FIG. **2** and FIG. **3**, the chip **50** is located at the earbud part **1**. The chip **50** is fastened to the first connection part **402** of the circuit board **40**. The chip **50** may be fastened by welding and electrically connected to the circuit board **40**. The chip **50** may be a processing and control center for the bluetooth earphone **100**. The chip **50** is coupled to a plurality of functional modules of the bluetooth earphone **100** by using the circuit board **40**, to control the plurality of functional modules to work. For example, the chip **50** may be a system on chip (SOC).

In some embodiments, as shown in FIG. **2** and FIG. **3**, the earpiece module **60** is located at the earbud part **1**. The earpiece module **60** is connected to the first connection part **402** of the circuit board **40**. The earpiece module **60** is coupled to the chip **50**. The earpiece module **60** is configured to convert an electrical signal into a sound signal. The earpiece module **60** is located at a side of the chip **50** that is away from the earphone handle part **2**. In this case, the earpiece module **60** is closer to the outside of the bluetooth earphone **100**, and a sound signal formed by the earpiece module **60** is more easily output to the outside of the bluetooth earphone **100**. The bluetooth earphone **100** may further include a fixed terminal pair **601**. The fixed terminal pair **601** is located at the earbud part **1**. The fixed terminal pair **601** is fixedly connected to the first connection part **402** of the circuit board **40**. A connection terminal **602** of the earpiece module **60** is inserted to the fixed terminal pair **601** to electrically connect the circuit board **40**.

In some embodiments, as shown in FIG. **2** and FIG. **3**, the battery **70** is located at the bottom section **23** of the earphone handle part **2**. The battery **70** is connected to the second end part **405** of the circuit board **40**. The battery **70** is coupled to the chip **50**. The battery **70** is configured to supply power to the bluetooth earphone **100**. In this embodiment, the battery **70** is in a strip shape to be better accommodated in the main housing **101**. In another embodiment, the battery **70** may be in another shape. In some other embodiments, the battery **70** may be connected to the second connection part **403** of the circuit board **40**.

In some embodiments, as shown in FIG. **2** and FIG. **3**, the first microphone module **90** is located at the bottom section **23** of the earphone handle part **2**. The first microphone module **90** may be located at a side of the battery **70** that is away from the antenna **20**. The first microphone module **90** is connected to the second end part **405** of the circuit board **40**. The first microphone module **90** is coupled to the chip **50**. The first microphone module **90** is configured to convert a sound signal into an electrical signal.

The second microphone module **110** is located at the connecting section **21** of the earphone handle part **2**. The second microphone module **110** is located at a side of the battery **70** that is close to the antenna **20**. The second microphone module **110** is connected to the second connection part **403** of the circuit board **40**. The second microphone module **110** is coupled to the chip **50**. The second microphone module **110** is configured to convert a sound signal into an electrical signal. The second microphone module **110** and the first microphone module **90** may cooperate to improve speech recognition accuracy of the bluetooth earphone **100**. Alternatively, the second microphone module **110** and the first microphone module **90** may work independently.

It may be understood that components of the bluetooth earphone **100** are not limited to the foregoing functional modules, and the bluetooth earphone **100** may include more functional modules (for example, a proximity sensor module or a bone vibration module) or fewer functional modules. This is not strictly limited.

FIG. **4** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **2** in an embodiment. FIG. **4** is a simple schematic diagram of a structure when the circuit board **40** is in a flat state and does not define a shape of the circuit board **40**.

The circuit board **40** includes a feeding pad **41**, a ground plane **42**, a first grounding branch **43**, and a second grounding branch **44**. The feeding pad **41** is located at a feeding part **401**. The feeding pad **41** is configured to fasten a conductive member **80** to be coupled to an antenna **20**. The ground plane **42** is located at the feeding part **401** and spaced from the feeding pad **41**. The ground plane **42** is grounded and serves as a part of a current return path of the antenna **20**. For example, the ground plane **42** and the feeding pad **41** are located at different conductive layers of the circuit board **40** to form a gap therebetween. For example, the feeding pad **41** is located at a surface conductive layer of the circuit board **40**, and the ground plane **42** is located at an inner conductive layer or another surface conductive layer of the circuit board **40**. In some other embodiments, the ground plane **42** and the feeding pad **41** may be located at a same layer and form a gap therebetween, so as not to touch each other.

One end of the first grounding branch **43** is connected to the ground plane **42** and the other end extends to the first end part **404**. The first grounding branch **43** is connected in series to a first switch **431**. When the first switch **431** is on, the first grounding branch **43** is configured to form a ground current, and the first grounding branch **43** serves as a part of the current return path of the antenna **20**. When the first switch **431** is off, the first switch **431** cuts off a current on the first grounding branch **43**, and the first grounding branch **43** does not provide an effective current return path for the antenna **20**.

One end of the second grounding branch **44** is connected to the ground plane **42** and the other end extends to the second end part **405**. The second grounding branch **44** is connected in series to a second switch **441**. When the second switch **441** is on, the second grounding branch **44** is configured to form a ground current, and the second grounding branch **44** serves as a part of the current return path of the antenna **20**. When the second switch **441** is off, the second switch **441** cuts off a current on the second grounding branch **44**, and the second grounding branch **44** does not provide an effective current return path for the antenna **20**.

In this embodiment, the bluetooth earphone **100** may form a plurality of ground structures by controlling states (on or off) of the first switch **431** and the second switch **441**, and select different grounding branches, in other words, select different current return paths, for the antenna **20** by switching the ground structures, to switch radiation patterns of the antenna. The radiation patterns of the antenna **20** in the plurality of ground structures are complementary. Therefore, the antenna **20** has no obvious null in each radiation direction, and antenna gains of the antenna **20** in all directions are relatively even, thereby improving communication quality and resolving a problem of poor communication experience caused by low gains of the antenna at some angles.

FIG. **5** is a schematic current diagram of a partial structure of the bluetooth earphone **100** shown in FIG. **3**, and FIG. **6** is a schematic diagram of a partial structure of the feeding part **401** of the circuit board **40** shown in FIG. **4** in some embodiments.

As shown in FIG. **4** and FIG. **5**, the antenna **20** is configured to form a first current **3***a*. The first current **3***a* is an antenna current. A flow direction of the first current **3***a* varies with a shape direction of the antenna **20**. The antenna **20** includes a feeding end **201** and an end **202** away from the feeding end **201**. The feeding end **201** is connected to the feeding pad **41** by using a conductive member **80** to be coupled to the feeding part **401**. The first current **3***a* extends from the feeding end **201** to the end **202** and a direction of the first current **3***a* is from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**.

The antenna **20** may be a quarter-wavelength antenna, to have relatively high antenna efficiency. An electrical length of the antenna **20** may be implemented by adjusting a physical length of the antenna **20**. For example, the antenna **20** has a spiral shape, to overcome a problem that insufficient space of the top section **22** of the earphone handle part **2** increases the length of the antenna **20**, so that the electrical length of the first current **3***a* formed on the antenna **20** can satisfy the quarter wavelength requirement. Further, the physical length of the antenna **20** may be changed by changing a winding loop quantity, a winding density, a winding shape, and the like of the antenna **20**. In another embodiment, the antenna **20** may be provided in a structure having a plurality of layers of stacked antenna segments. A shape of the antenna **20** is not strictly limited.

As shown in FIG. **4** and FIG. **5**, when the first switch **431** is on, the first grounding branch **43** is configured to form a second current **3***b*. The second current **3***b* is a ground current. The second current **3***b* extends from an end of the first grounding branch **43** that is away from the ground plane **42** to the ground plane **42**. The second current **3***b* extends from a first end part **404** of the circuit board **40** to the feeding part **401**, and a direction of the second current **3***b* is from the earbud part **1** to the connecting section **21** of the earphone handle part **2**. A flow direction of the second current **3***b* varies with a shape direction of the circuit board **40**.

In some embodiments, when the first switch **431** is on, an electrical length of the first grounding branch **43** is or is close to a quarter wavelength, so that the second current **3***b* is in resonant mode and effective radiation can be formed. The first switch **431** may be located at the feeding part **401** (as shown in FIG. **4** and FIG. **6**) of the circuit board **40** or located at an end of the first connection part **402** that is close to the feeding part **401**. In this case, an electrical length of a part of the first grounding branch **43** that is located between the first switch **431** and the ground plane **42** is less than a quarter wavelength, a current on the part is not in resonant mode, and effective radiation cannot be formed. It may be understood that, in some other embodiments, the first switch **431** may be located elsewhere, provided that the electrical length of the part of the first grounding branch **43** that is located between the first switch **431** and the ground plane **42** is not equal to N/4 wavelengths, where N is a positive integer.

As shown in FIG. **4** and FIG. **5**, when the second switch **441** is on, the second grounding branch **44** is configured to form a third current **3***c*. The third current **3***c* is a ground current. The third current **3***c* extends from an end of the second grounding branch **44** that is away from the ground plane **42** to the ground plane **42**. The third current **3***c* extends from a second end part **405** of the circuit board **40** to the feeding part **401**, and a direction of the third current **3***c* is from the bottom section **23** of the earphone handle part **2** to the connecting section **21** of the earphone handle part **2**. A flow direction of the third current **3***c* varies with a shape direction of the circuit board **40**.

In some embodiments, when the second switch **441** is on, an electrical length of the second grounding branch **44** is or is close to a quarter wavelength, so that the third current **3***c* is in resonant mode and effective radiation can be formed. The second switch **441** may be located at the feeding part **401** (as shown in FIG. **4** and FIG. **6**) of the circuit board **40** or located at an end of the second connection part **403** that is close to the feeding part **401**, for example, located between the chip **50** and the ground plane **42**. In this case, an electrical length of a part of the first grounding branch **43** that is located between the first switch **431** and the ground plane **42** is less than a quarter wavelength, a current on the part is not in resonant mode, and effective radiation cannot be formed. It may be understood that, in some other embodiments, the second switch **441** may be located elsewhere, provided that the electrical length of the part of the first grounding branch **43** that is located between the first switch **431** and the ground plane **42** is not equal to N/4 wavelengths, where N is a positive integer.

It may be understood that, because the first current **3***a* is an alternating current, directions of the first current **3***a*, the second current **3***b*, and the third current **3***c* may have two states. FIG. **5** illustrates one state. In the other state, the direction of the first current **3***a* is from the top section **22** of the earphone handle part **2** to the connecting section **21** of the earphone handle part **2**, the direction of the second current **3***b* is from the connecting section **21** of the earphone handle part **2** to the earbud part **1**, and the direction of the third current **3***c* is from the connecting section **21** of the earphone handle part **2** to the bottom section **23** of the earphone handle part **2**.

It may be understood that, in the embodiments, carrier media of the first current **3***a*, the second current **3***b*, and the third current **3***c* each with an electrical length of a quarter wavelength (namely, the antenna **20**, the first grounding branch **43**, and the second grounding branch **44**) are affected by a medium around paths of the antenna **20**, the first grounding branch **43**, and the second grounding branch **44**, each with an actual physical length smaller than a quarter wavelength.

FIG. **7** is a schematic diagram of an equivalent current of the structure shown in FIG. **5**. For convenience of description below, the first current **3***a* is equivalent to a first equivalent current **3***a*' shown in FIG. **7**, the second current **3***b* is equivalent to a second equivalent current **3***b*' shown in FIG. **7**, and the third current **3***c* is equivalent to a third equivalent current **3***c*' shown in FIG. **7**.

FIG. **8** is a schematic diagram of a radiation field pattern **51** of the bluetooth earphone **100** shown in FIG. **1** in a first ground structure of the circuit board **40** shown in FIG. **4**.

When the first switch **431** of the circuit board **40** is on and the second switch **441** is off, the first ground structure is formed. The antenna **20** forms a first current **3***a*, the first current **3***a* is equivalent to a first equivalent current **3***a*' in FIG. **8**, and the first equivalent current **3***a*' extends from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**. The first switch **431** is on and the second switch **441** is off, the first grounding branch **43** serves as a current return path, the first grounding branch **43** forms a second current **3***b*, the second current **3***b* is equivalent to a second equivalent current **3***b*' in FIG. **8**, and the second equivalent current **3***b*' extends from the earbud part **1** to the connecting section **21** of the earphone handle part **2**. The second current **3***b* and the first current **3***a* are capable of composing into an equivalent current **3***d* in resonant mode, and the equivalent current **3***d* extends from the earbud part **1** to the top section **22** of the earphone handle part **2**.

When an electrical length of the first current **3***a* is a quarter wavelength and an electrical length of the second current **3***b* is a quarter wavelength, an electrical length of the equivalent current **3***d* composed by the first current **3***a* and the second current **3***b* is a half wavelength, and the equivalent current **3***d* is in resonant mode, so that an antenna signal is effectively radiated. When the circuit board **40** is in the first ground structure, the radiation field pattern **51** of the bluetooth earphone **100** is shown in FIG. **8**. A line connecting a radiation null **52** of the radiation field pattern **51** and a central point **54** is parallel to the equivalent current **3***d*, and a line connecting a radiation intensity point **53** and the central point **54** is perpendicular to the equivalent current **3***d*.

In this embodiment, because the direction of the first current **3***a* is from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**, and the direction of the second current **3***b* is from the earbud part **1** to the connecting section **21** of the earphone handle part **2**, the direction of the equivalent current **3***d* composed by the first current **3***a* and the second current **3***b* is from the earbud part **1** to the top section **22** of the earphone handle part **2**. Therefore, when a user wears the bluetooth earphone **100**, the radiation null **52** of the radiation field pattern **51** of the antenna **20** of the bluetooth earphone **100** is toward the user head, thereby greatly reducing an adverse effect of the user head to the antenna **20** and enabling the antenna **20** to have better antenna performance.

FIG. **9** is a schematic diagram of a radiation field pattern **51** of the bluetooth earphone **100** shown in FIG. **1** in a second ground structure of the circuit board **40** shown in FIG. **4**. When the second switch **441** of the circuit board **40** is on and the first switch **431** is off, the second ground structure is formed. The antenna **20** forms a first current **3***a*, the first current **3***a* is equivalent to a first equivalent current **3***a*' in FIG. **9**, and the first equivalent current **3***a*' extends from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**. When the second switch **441** is on and the first switch **431** is off, the second grounding branch **44** serves as a current return path, and the second grounding branch **44** forms a third current **3***c*. The third current **3***c* is equivalent to a third equivalent current **3***c*' in FIG. **9**, and the third equivalent current **3***c*' extends from the bottom section **23** of the earphone handle part **2** to the connecting section **21** of the earphone handle part **2**. The third current **3***c* and the first current **3***a* are capable of composing into an equivalent current **3***d* in resonant mode, and the equivalent current **3***d* extends from the bottom section **23** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**. In FIG. **9**, for convenience of illustration, the equivalent current **3***d* is illustrated differently from the first equivalent current **3***a*' and the third equivalent current **3***c*'. Actually, the equivalent current **3***d*, the first equivalent current **3***a*', and the third equivalent current **3***c*' should be overlapping.

When an electrical length of the first current **3***a* is a quarter wavelength and an electrical length of the third current **3***c* is a quarter wavelength, an electrical length of the equivalent current **3***d* composed by the first current **3***a* and the third current **3***c* is a half wavelength, and the equivalent current **3***d* is in resonant mode, so that an antenna signal is effectively radiated. When the circuit board **40** is in the second ground structure, the radiation field pattern **51** of the bluetooth earphone **100** is shown in FIG. **9**. A line connecting a radiation null **52** of the radiation field pattern **51** and a central point **54** is parallel to the equivalent current **3***d*, and a line connecting a radiation intensity point **53** and the central point **54** is perpendicular to the equivalent current **3***d*.

FIG. **10** is a schematic diagram of a radiation field pattern **51** of the bluetooth earphone **100** shown in FIG. **1** in a third ground structure of the circuit board **40** shown in FIG. **4**. When the first switch **431** of the circuit board **40** is on and the second switch **441** is on, the third ground structure is formed. The antenna **20** forms a first current **3***a*, the first current **3***a* is equivalent to a first equivalent current **3***a*' in FIG. **10**, and the first equivalent current **3***a*' extends from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**. When the first switch **431** is on and the second switch **441** is on, the first grounding branch **43** and the second grounding branch **44** serve as current return paths. The first grounding branch **43** forms a second current **3***b*, the second current **3***b* is equivalent to a second equivalent current **3***b*' in FIG. **10**, and the second equivalent current **3***b*' extends from the earbud part **1** to the connecting section **21** of the earphone handle part **2**. The second grounding branch **44** forms a third current **3***c*, the third current **3***c* is equivalent to a third equivalent current **3***c*' in FIG. **10**, and the third equivalent current **3***c*' extends from the bottom section **23** of the earphone handle part **2** to the connecting section **21** of the earphone handle part **2**. The first current **3***a*, the second current **3***b*, and the third current **3***c* are capable of composing into an equivalent current **3***d* in resonant mode, and the equivalent current **3***d* extends from the underside of the earbud part **1** (namely, the side near the bottom section **23** of the earphone handle part **2**) to the top section **22** of the earphone handle part **2**.

When an electrical length of the first current **3***a* is a quarter wavelength, an electrical length of the second current **3***b* is a quarter wavelength, and an electrical length of the third current **3***c* is a quarter wavelength, an electrical length of the equivalent current **3***d* composed by the first current **3***a*, the second current **3***b*, and the third current **3***c* is a three-quarter wavelength, and the equivalent current **3***d* is in resonant mode, so that an antenna signal is effectively radiated. When the circuit board **40** is in the third ground structure, the radiation field pattern **51** of the bluetooth earphone **100** is shown in FIG. **10**. A line connecting a radiation null **52** of the radiation field pattern **51** and a central point **54** is parallel to the equivalent current **3***d*, and a line connecting a radiation intensity point **53** and the central point **54** is perpendicular to the equivalent current **3***d*.

With reference to FIG. **8** to FIG. **10**, in different ground structures, the antenna **20** of the bluetooth earphone **100** forms equivalent currents **3***d* in different directions, and the radiation field patterns **51** formed by the antenna **20** are complementary. The bluetooth earphone **100** may switch the ground structures of the circuit board **40** to change locations of the radiation null **52** and the radiation intensity point **53** of the radiation field pattern **51** of the antenna **20**. Therefore, the antenna **20** has no obvious radiation null **52** in a radiation direction, and antenna gains of the antenna **20** in all directions are relatively even, thereby improving communication quality.

It may be understood that, in some embodiments, the circuit board **40** shown in FIG. **4** may have the foregoing first and second ground structures. In this case, the first switch **431** and the second switch **441** may be single-pole single-throw switches independent of each other or may be integrated into a single-pole double-throw switch. In some other embodiments, the circuit board **40** shown in FIG. **4** may have the foregoing first, second, and third ground structures. In this case, the first switch **431** and the second switch **441** may be single-pole single-throw switches independent of each other.

FIG. **11**A is a simulation diagram of a radiation field pattern of the bluetooth earphone **100** when the circuit board **40** shown in FIG. **4** is switched to a first ground structure. FIG. **11**B is a simulation diagram of a radiation field pattern of the bluetooth earphone **100** when the circuit board **40** shown in FIG. **4** is switched to a second ground structure. FIG. **11**C is a simulation diagram of a radiation field pattern of the bluetooth earphone **100** when the circuit board **40** shown in FIG. **4** is switched to a third ground structure.

FIG. **11**A to FIG. **11**C illustrate again, by using simulation diagrams, the radiation field patterns of the antenna **20** of the bluetooth earphone **100** corresponding to the first ground structure, the second ground structure, and the third ground structure. The radiation field patterns of the antenna **20** corresponding to different ground structures are complementary.

As shown in FIG. **11**A, when the circuit board **40** switches to the first ground structure, the second switch **441** is off, some currents on a part of the second grounding branch **44** that is between the second switch **441** and the ground plane **42** may participate in radiation, and a radiation participation proportion is obviously smaller than that of other currents in a resonance state (namely, the first current **3***a* and the second current **3***b*). Therefore, a direction of an effective radiation current (a composed current of all the radiation participation currents) of the antenna **20** rotates a little counterclockwise relative to the equivalent current **3***d* in FIG. **8**. Adaptively, the direction of the radiation field pattern of the antenna **20** rotates counterclockwise relative to the radiation field pattern **51** in FIG. **8**.

As shown in FIG. **11**B, when the circuit board **40** switches to the second ground structure, the first switch **431** is off, some currents on a part of the first grounding branch **43** that is between the first switch **431** and the ground plane **42** may participate in radiation, and a radiation participation proportion is obviously smaller than that of other currents in a resonance state (namely, the first current **3***a* and the third current **3***c*). Therefore, a direction of an effective radiation current of the antenna **20** rotates a little clockwise relative to the equivalent current **3***d* in FIG. **9**. Adaptively, the direction of the radiation field pattern of the antenna **20** rotates clockwise relative to the radiation field pattern **51** in FIG. **9**.

FIG. **12** is a comparison radiation pattern of a vertical section of the bluetooth earphone **100** shown in FIG. **1** in free space in a plurality of ground structures of the circuit board **40** shown in FIG. **4**. In the radiation pattern of FIG. **12**, a dashed outline illustrates a radiation pattern of the bluetooth earphone **100** corresponding to a first ground structure of the circuit board **40** shown in FIG. **4**, a dot-dashed outline illustrates a radiation pattern of the bluetooth earphone **100** corresponding to a second ground structure of the circuit board **40** shown in FIG. **4**, and a straight outline illustrates a radiation pattern of the bluetooth earphone **100** corresponding to a third ground structure of the circuit board **40** shown in FIG. **4**.

FIG. **12** illustrates that the radiation field patterns of the antenna **20** of the bluetooth earphone **100** corresponding to the different ground structures are complementary. The bluetooth earphone **100** may change locations of the radiation null and the radiation intensity point of the radiation field pattern of the antenna **20** by switching the ground structures of the circuit board **40**. Therefore, the antenna **20** has no obvious radiation null in a radiation direction, and antenna gains of the antenna **20** in all directions are relatively even, thereby improving communication quality.

FIG. **13**A is a simulation diagram of a radiation field pattern of a bluetooth earphone **100** corresponding to a head mode in free space when the circuit board **40** shown in FIG. **4** is switched to a first ground structure. FIG. **13**B is a simulation diagram of a radiation field pattern of a bluetooth earphone **100** corresponding to a head mode in free space when the circuit board **40** shown in FIG. **4** is switched to a second ground structure. FIG. **13**C is a simulation diagram of a radiation field pattern of a bluetooth earphone **100** corresponding to a head mode in free space when the circuit board **40** shown in FIG. **4** is switched to a third ground structure. FIG. **14**A is a simulation diagram of a radiation field pattern of a bluetooth earphone **100** corresponding to a head mode when the circuit board **40** shown in FIG. **4** is switched to a first ground structure. FIG. **14**B is a simulation diagram of a radiation field pattern of a bluetooth earphone **100** corresponding to a head mode when the circuit board **40** shown in FIG. **4** is switched to a second ground structure. FIG. **14**C is a simulation diagram of a radiation field pattern of a bluetooth earphone **100** corresponding to a head mode when the circuit board **40** shown in FIG. **4** is switched to a third ground structure.

It can be learned from the simulation diagrams of FIG. **13**A to FIG. **14**C that, when a user wears the bluetooth earphone **100**, an antenna **20** of the bluetooth earphone **100** has different and complementary locations for radiation nulls and radiation intensity points in different ground structures. In addition, the different ground structures of the bluetooth earphone **100** may be switched to each other, so that the antenna **20** of the bluetooth earphone **100** has no obvious radiation null in a radiation direction, thereby ensuring communication quality.

FIG. **15**A is a comparison radiation pattern of the bluetooth earphone **100** shown in FIG. **1** corresponding to a vertical section of a head mode in a plurality of ground structures of the circuit board **40** shown in FIG. **4**. FIG. **15**B is a comparison radiation pattern of the bluetooth earphone **100** shown in FIG. **1** corresponding to a horizontal section of a head mode in a plurality of ground structures of the circuit board **40** shown in FIG. **4**. In the radiation patterns of FIG. **15**A and FIG. **15**B, dashed outlines illustrate the radiation patterns of the bluetooth earphone **100** corresponding to the vertical section and the horizontal section of the head mode in a first ground structure of the circuit board **40** shown in FIG. **4**, dot outlines illustrate the radiation patterns of the bluetooth earphone **100** corresponding to the vertical section and the horizontal section of the head mode in a second ground structure of the circuit board **40** shown in FIG. **4**, and straight outlines illustrate the radiation patterns of the bluetooth earphone **100** corresponding to the vertical section and the horizontal section of the head mode in a third ground structure of the circuit board **40** shown in FIG. **4**.

FIG. **15**A and FIG. **15**B illustrate that, when the bluetooth earphone **100** is worn on a user head, the antenna **20** that can be switched between the plurality of ground structures has relatively even antenna gains in all directions of the vertical section or the horizontal section, without an obvious null, and communication quality of the antenna **20** is relatively high.

It may be understood that the bluetooth earphone **100** can interact with a bluetooth antenna of an electronic device. The electronic device may be a product such as a mobile phone, a tablet, a computer, or an intelligent wearable device. When the electronic device is placed in different states, the bluetooth antenna of the electronic device has different polarization directions, and the polarization directions of the bluetooth antenna vary with the placement states of the electronic device. In this embodiment, the bluetooth earphone **100** can change the radiation pattern of the antenna **20** of the bluetooth earphone **100** by switching the ground structures. Then a polarization direction of the antenna **20** changes and becomes similar to the polarization direction of the bluetooth antenna of the electronic device, thereby reducing a path loss caused by a polarization difference in a communication process between the bluetooth earphone **100** and the electronic device.

FIG. **16** is a schematic diagram of the bluetooth earphone **100** shown in FIG. **1** in a use state. As shown in FIG. **16**, when the bluetooth earphone **100** communicates with an electronic device, the electronic device and the bluetooth earphone **100** may be located at a same side or at opposite sides of a head mode. In some embodiments, as shown in FIG. **15**A, the antenna **20** of the bluetooth antenna **100** has a higher antenna gain when the bluetooth earphone **100** and the electronic device are located at opposite sides of the head mode in the third ground structure, or when the bluetooth earphone **100** and the electronic device are located at the same side of the head mode in the first ground structure and the second ground structure. Therefore, the bluetooth earphone **100** may switch the radiation patterns by switching the ground structures, to better communicate with the electronic device.

In some embodiments, the first grounding branch **43** is further connected in series to a first choke inductor **432**, and the first choke inductor **432** is disposed in parallel with the first switch **431**. In this embodiment, the first grounding branch **43** is not only configured to provide a current return path for the antenna **20**, but also configured to provide a reference ground for another functional module of the bluetooth earphone **100**. Because the first choke inductor **432** is disposed in parallel with the first switch **431**, and the first choke inductor **432** is connected in series to the first grounding branch **43**, the first grounding branch **43** as a reference ground for a low frequency signal is continuous and complete. For example, the earpiece module **60** is connected to the first grounding branch **43**, and the first grounding branch **43** is further configured to provide a reference ground for the earpiece module **60**. For example, an inductance value of the first choke inductor **432** may be greater than or equal to 22 nanohenries (nH) to block a signal in the bluetooth frequency band (2.4 GHz) and allow passage of a low frequency signal that is below the bluetooth frequency band. For example, the inductance value of the first choke inductor **432** may be 82 nanohenries (nH).

In some embodiments, the second grounding branch **44** is further connected in series to a second choke inductor **442**, and the second choke inductor **442** is disposed in parallel with the second switch **441**. In this embodiment, the second grounding branch **44** is not only configured to provide a current return path for the antenna **20**, but also configured to provide a reference ground for another functional module of the bluetooth earphone **100**. Because the second choke inductor **442** is disposed in parallel with the second switch **441**, and the second choke inductor **442** is connected in series to the second grounding branch **44**, the second grounding branch **44** as a reference ground for a low frequency signal is continuous and complete. For example, the first microphone module **90** is connected to the second grounding branch **44**, and the second grounding branch **44** is further configured to provide a reference ground for the first microphone module **90**. For example, an inductance value of the second choke inductor **442** may be greater than or equal to 22 nanohenries (nH) to block a signal in the bluetooth frequency band (2.4 GHz) and allow passage of a low frequency signal that is below the bluetooth frequency band. For example, the inductance value of the second choke inductor **442** may be 82 nanohenries (nH).

In some embodiments, the circuit board **40** further includes a first low-frequency signal line **45**, a second low-frequency signal line **46**, and a chip pad **47**. The chip pad **47** is located at the first connection part **402** of the circuit board **40** and configured to fasten the chip **50**. One end of the first low-frequency signal line **45** is connected to the chip pad **47** to connect to the chip **50**, and the other end of the first low-frequency signal line **45** extends to the first end part **404**. The first low-frequency signal line **45** may be connected to another functional module of the bluetooth earphone **100** and is configured to transmit a low frequency signal between the functional module and the chip **50**. For example, the earpiece module **60** is connected to the first low-frequency signal line **45**. The first low-frequency signal line **45** transmits a signal between the earpiece module **60** and the chip **50**.

The first low-frequency signal line **45** is connected in series to a third choke inductor **451**. Because some locations of the first low-frequency signal line **45** may be capacitively coupled to the first grounding branch **43**, the first low-frequency signal line **45** is connected in series to the third choke inductor **451**, and the first low-frequency signal line **45** is isolated from the ground at a high frequency by using the third choke inductor **451**. For example, an inductance value of the third choke inductor **451** may be greater than or equal to 22 nanohenries. For example, the inductance value of the third choke inductor **451** may be 82 nanohenries.

One end of the second low-frequency signal line **46** is connected to the chip pad **47** to connect to the chip **50**, and the other end of the second low-frequency signal line **46** extends to the second end part **405**. The second low-frequency signal line **46** may be connected to another functional module of the bluetooth earphone **100** and is configured to transmit a low frequency signal between the functional module and the chip **50**. For example, the first microphone module **90** is connected to the first low-frequency signal line **45**. The first low-frequency signal line **45** transmits a signal between the first microphone module **90** and the chip **50**.

The second low-frequency signal line **46** is connected in series to a fourth choke inductor **461**. Because some locations of the second low-frequency signal line **46** may be capacitively coupled to the second grounding branch **44**, the second low-frequency signal line **46** is connected in series to the fourth choke inductor **461**, and the second low-frequency signal line **46** is isolated from the ground at a high frequency by using the fourth choke inductor **461**. For example, an inductance value of the fourth choke inductor **461** may be greater than or equal to 22 nanohenries. For example, the inductance value of the fourth choke inductor **461** may be 82 nanohenries.

In some embodiments, the circuit board **40** further includes a first power cable **47** and a second power cable **48**. One end of the first power cable **47** is connected to the chip pad **47** to connect to the chip **50**, and the other end of the first power cable **47** extends to the first end part **404**. One end of the second power cable **48** is connected to the chip pad **47** to connect to the chip **50**, and the other end of the second power cable **48** extends to the second end part **405**. The first power cable **47** and the second power cable **48** are connected to a power management module of the chip **50**. The second power cable **48** is connected to a battery **70**, and the power management module is configured to control a charging/discharging process of the battery **70** and a power supply process for another functional module. The first power cable **47** and the second power cable **48** are further configured to connect to another functional module of the bluetooth earphone **100**, such as the earpiece module **60** or the first microphone module **90**, so that the battery can supply power to the functional module of the bluetooth earphone **100**.

A fifth choke inductor **471** may be connected in series to the first power cable **47**, and a sixth choke inductor **481** may be connected in series to the second power cable **48**. For example, the fifth choke inductor **471** and the sixth choke inductor **481** may be greater than or equal to 22 nanohenries, for example, may be 82 nanohenries.

It may be understood that the second microphone module **110** of the bluetooth earphone **100** may be connected to the second low-frequency signal line **46**, the second grounding branch **44**, and the second power cable **48**. Other modules of the bluetooth earphone **100** may further include a sensor module, and the sensor module may be connected to the first low-frequency signal line **45**, the first grounding branch **43**, and the first power cable **47**.

In some embodiments, the circuit board **40** further includes a matching circuit **49** and a radio frequency circuit **410**. For example, the radio frequency circuit **410** is located at a radiation part **401**, and the matching circuit **49** is connected between the radio frequency circuit **410** and the feeding pad **41**.

The matching circuit **49** may include one or more of a capacitor, an inductor, or a resistor. For example, the matching circuit may include a 1.3-picofarad (pF) capacitor and a 10-nanohenry inductor. In this embodiment, because effective electrical lengths of the first grounding branch **43** and the second grounding branch **44** are similar or the same, the circuit board **40** does not need to provide two matching circuits or an antenna switch for switching the two matching circuits. The circuit board **40** may use one matching circuit **49**, thereby simplifying a circuit structure of the circuit board **40** and reducing costs of the circuit board **40**.

The radio frequency circuit **410** is configured to process a radio frequency signal. The radio frequency circuit **410** is configured to modulate or demodulate a radio frequency signal. The radio frequency circuit **410** is connected to the chip pad **47** to connect to the chip **50**.

FIG. **17** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **2** in another embodiment. The following describes a difference between the circuit board **40** in this embodiment and the circuit board **40** in the foregoing embodiments, and most content that is the same as that of the circuit board **40** in the foregoing embodiments is not described again. In this embodiment, the radio frequency circuit **410** of the circuit board **40** may be located at the first connection part **402**. The matching circuit **49** is still located at the feeding part **401**, to keep a relatively small distance from the feeding pad **41**, so that a radio frequency signal transmitted and received by the feeding pad **41** has higher quality.

In another embodiment, a radio frequency processing module may be disposed on the chip **50** of the bluetooth earphone **100**, to process a radio frequency signal. In this case, the radio frequency circuit **410** is no longer disposed on the circuit board **40**, and the radio frequency processing module of the chip **50** is connected to the matching circuit **49**.

In the foregoing embodiments, the electrical length of the first grounding branch **43** and the electrical length of the second grounding branch **44** may be adjusted in a plurality of manners. Examples are illustrated as follows:

In a first implementation, the first grounding branch **43** extends from the feeding part **401** to the first end part **404**. Therefore, the electrical length of the first grounding branch **43** may be implemented by adjusting the length of the first connection part **402**. The second grounding branch **44** extends from the feeding part **401** to the second end part **405**. Therefore, the electrical length of the second grounding branch **44** may be implemented by adjusting the length of the second connection part **403**.

FIG. **18** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **4** in the first implementation. The first connection part **402** includes a plurality of sequentially connected regions, and the plurality of regions include one or more flat regions **4021** and one or more bent regions **4022**. The length of the first connection part **402** may be effectively adjusted in a manner of bending or stretching by increasing or decreasing a quantity or area of the flat regions **4021** and the bent regions **4022**, to adjust the length of the first grounding branch **43**, so that the electrical length of the first grounding branch **43** meets a requirement.

The second connection part **403** includes a plurality of sequentially connected regions, and the plurality of regions include one or more flat regions **4031** and one or more bent regions **4032**. The length of the second connection part **403** may be effectively adjusted in a manner of bending or stretching by increasing or decreasing a quantity or area of the flat regions **4031** and the bent regions **4032**, to adjust the length of the second grounding branch **44**, so that the electrical length of the second grounding branch **44** meets a requirement.

In some embodiments, as shown in FIG. **18**, the electrical length of the second grounding branch **44** may be implemented by adjusting a length of the second end part **405**. For example, the second end part **405** includes a plurality of sequentially connected regions, and the plurality of regions include one or more flat regions **4051** and one or more bent regions **4052**. The length of the second end part **405** may be effectively adjusted in a manner of bending or stretching by increasing or decreasing a quantity or area of the flat regions **4051** and the bent regions **4052**, to adjust the length of the second grounding branch **44**, so that the electrical length of the second grounding branch **44** meets a requirement.

In a second implementation, as current return paths of the antenna **20**, the first grounding branch **43** and the second grounding branch **44** work in a bluetooth frequency band. In the embodiments, a low-pass high-resistance element may be connected in series to the first grounding branch **43** and the second grounding branch **44**, to adjust electrical lengths of the first grounding branch **43** and the second grounding branch **44**.

FIG. **19** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **4** in the second implementation. The first grounding branch **43** is further connected in series to a first low-pass high-resistance element **433**, and the first low-pass high-resistance element **433** is disposed in series with the first switch **431** and is located at a side of the first switch **431** that is away from the ground plane **42**. The first low-pass high-resistance element **433** is configured to allow passage of a current whose frequency band is lower than the bluetooth signal frequency band and prevent passage of a current whose frequency band is close to the bluetooth signal frequency band. In this case, the first low-pass high-resistance element **433** changes the electrical length of the first grounding branch **43** as the current return path of the antenna **20**, so that the first grounding branch **43** meets the electrical length requirement, without affecting a function of the first grounding branch **43** as a reference ground for a low frequency signal. For example, the first low-pass high-resistance element **433** may be located at the first connection part **402** or the first end part **404**.

The second grounding branch **44** is further connected in series to a second low-pass high-resistance element **443**, and the second low-pass high-resistance element **443** is disposed in series with the second switch **441** and is located at a side of the second switch **441** that is away from the ground plane **42**. The second low-pass high-resistance element **443** is configured to allow passage of a current whose frequency band is lower than the bluetooth signal frequency band and prevent passage of a current whose frequency band is close to the bluetooth signal frequency band. In this case, the second low-pass high-resistance element **443** changes the electrical length of the second grounding branch **44** as the current return path of the antenna **20**, so that the second grounding branch **44** meets the electrical length requirement, without affecting a function of the second grounding branch **44** as a reference ground for a low frequency signal. For example, the second low-pass high-resistance element **443** may be located at the second connection part **403** or the second end part **405**.

The first low-pass high-resistance element **433** and the second low-pass high-resistance element **443** may be inductors or magnetic beads. For example, when the first low-pass high-resistance element **433** and the second low-pass high-resistance element **443** are inductors, an impedance of the inductor may be greater than 1 nanohenry, for example, may be in the range of 20 nanohenries to 70 nanohenries.

In another implementation, the electrical length of the first grounding branch **43** and the electrical length of the second grounding branch **44** may be adjusted by using a combination solution of the foregoing two implementations.

FIG. **20** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **2** in still another embodiment. The following describes a difference between the circuit board **40** in this embodiment and the circuit board **40** in the foregoing embodiments, and most content that is the same as that of the circuit board **40** in the foregoing embodiments is not described again. In FIG. **20**, a part of the second connection part **403** that is located at the dashed line frame includes a plurality of bent parts. For simplification, FIG. **20** illustrates that a wire passing through the part is bent a plurality of times while the contour of this part is illustrated in a straight line.

The circuit board **40** includes a feeding pad **41**, a ground plane **42**, a first grounding branch **43**, and a second grounding branch **44**. The feeding pad **41** is located at a feeding part **401**. The feeding pad **41** is configured to be coupled to the antenna **20**. The ground plane **42** is located at the feeding part **401** and spaced from the feeding pad **41**. One end of the first grounding branch **43** is connected to the ground plane **42** and the other end extends to the first end part **404**. One end of the second grounding branch **44** is connected to the ground plane **42** and the other end extends to the second end part **405**. The electrical length of the first grounding branch **43** may be a quarter wavelength.

The second grounding branch **44** is connected in series to a first branch **444**. The second grounding branch **44** further includes a second branch **445**. One end of the second branch **445** is connected to one end of the first branch **444**, and the other end of the second branch **445** is connected or coupled to the other end of the first branch **444**. The end part of the second branch **445** is connected to the end part of the first branch **444** the end parts of the second branch **445** and the first branch **444** touch each other for direct structural connection and electrical connection. An end part of the second branch **445** is coupled to an end part of the first branch **444** the ends of the second branch **445** and the first branch **444** are close to each other to form a capacitance, thereby implementing electrical coupling. The second branch **445** is connected in series to a switch **446**. The second branch **445** is shorter than the first branch **444**.

In this embodiment, because a part of the second connection part **403** of the circuit board **40** that is close to the feeding part **401** is located at the connecting section **21** of the earphone handle part **2** of the bluetooth earphone **100**, the second connection part **403** needs to be folded inevitably. Therefore, the second connection part **403** is relatively long, and the second grounding branch **44** passing the second connection part **403** and extending to the second end part **405** is also relatively long. Because the second branch **445** is disposed in parallel with the first branch **444**, and the second branch **445** is shorter than the first branch **444**, when a switch **446** of the second branch **445** is off, a third current on the second grounding branch **44** selects the longer first branch **444** as a path, an electrical length of the second grounding branch **44** is greater than a quarter wavelength, and effective radiation is difficult to form. Therefore, a current return path of the antenna **20** is the first grounding branch **43**. When the switch **446** of the second branch **445** is on, the third current on the second grounding branch **44** selects the shorter second branch **445** as a path, an electrical length of the second grounding branch **44** can be shortened to a quarter wavelength to perform effective radiation, and both the second grounding branch **44** and the first grounding branch **43** serve as current return paths of the antenna **20**.

FIG. **21** is a schematic diagram of a radiation field pattern **51** of the bluetooth earphone **100** shown in FIG. **1** in a first ground structure of the circuit board **40** shown in FIG. **20**. When the switch **446** of the circuit board **40** is off, the first ground structure is formed. The antenna **20** forms a first current, the first current is equivalent to a first equivalent current **3***a*' in FIG. **21**, and the first equivalent current **3***a*' extends from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**. When the switch **446** is off, the first grounding branch **43** serves as a current return path, the first grounding branch **43** forms a second current, the second current is equivalent to a second equivalent current **3***b*' in FIG. **8**, and the second equivalent current **3***b*' extends from the earbud part **1** to the connecting section **21** of the earphone handle part **2**. The second current and the first current are capable of composing into an equivalent current **3***d* in resonant mode, and the equivalent current **3***d* extends from the earbud part **1** to the top section **22** of the earphone handle part **2**.

When an electrical length of the first current is a quarter wavelength and an electrical length of the second current is a quarter wavelength, an electrical length of the equivalent current **3***d* composed by the first current and the second current is a half wavelength, and the equivalent current **3*d*** is in resonant mode, so that an antenna signal is effectively radiated. When the circuit board **40** is in the first structure, the radiation field pattern **51** of the bluetooth earphone **100** is shown in FIG. **21**. A line connecting a radiation null **52** of the radiation field pattern **51** and a central point **54** is parallel to the equivalent current **3*d***, and a line connecting a radiation intensity point **53** and the central point **54** is perpendicular to the equivalent current **3*d***.

In this embodiment, because the direction of the first current is from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**, and the direction of the second current is from the earbud part **1** to the connecting section **21** of the earphone handle part **2**, the direction of the equivalent current **3*d*** composed by the first current and the second current is from the earbud part **1** to the top section **22** of the earphone handle part **2**. Therefore, when a user wears the bluetooth earphone **100**, the radiation null **52** of the radiation field pattern **51** of the antenna **20** of the bluetooth earphone **100** is toward the user head, thereby greatly reducing an adverse effect of the user head to the antenna **20** and enabling the antenna **20** to have better antenna performance.

FIG. **22** is a schematic diagram of a radiation field pattern **51** of the bluetooth earphone **100** shown in FIG. **1** in a second ground structure of the circuit board **40** shown in FIG. **20**. When the switch **446** of the circuit board **40** is on, the second ground structure is formed. The antenna **20** forms a first current, the first current is equivalent to a first equivalent current **3*a*'** in FIG. **22**, and the first equivalent current **3*a*'** extends from the connecting section **21** of the earphone handle part **2** to the top section **22** of the earphone handle part **2**. When the switch **446** is on, the first grounding branch **43** and the second grounding branch **44** serve as current return paths. The first grounding branch **43** forms a second current, the second current is equivalent to a second equivalent current **3*b*'** in FIG. **22**, and the second equivalent current **3*b*'** extends from the earbud part **1** to the connecting section **21** of the earphone handle part **2**. The second grounding branch **44** forms a third current, the third current is equivalent to a third equivalent current **3*c*'** in FIG. **22**, and the third equivalent current **3*c*'** extends from the bottom section **23** of the earphone handle part **2** to the connecting section **21** of the earphone handle part **2**. The first current, the second current, and the third current are capable of composing into an equivalent current **3*d*** in resonant mode, and the equivalent current **3*d*** extends from the underside of the earbud part **1** (namely, the side near the bottom section **23** of the earphone handle part **2**) to the top section **22** of the earphone handle part **2**.

When an electrical length of the first current is a quarter wavelength, an electrical length of the second current is a quarter wavelength, and an electrical length of the third current is a quarter wavelength, an electrical length of the equivalent current **3*d*** composed by the first current, the second current, and the third current is a three-quarter wavelength, and the equivalent current **3*d*** is in resonant mode, so that an antenna signal is effectively radiated. When the circuit board **40** is in the second structure, the radiation field pattern **51** of the bluetooth earphone **100** is shown in FIG. **22**. A line connecting a radiation null **52** of the radiation field pattern **51** and a central point **54** is parallel to the equivalent current **3*d***, and a line connecting a radiation intensity point **53** and the central point **54** is perpendicular to the equivalent current **3*d***.

With reference to FIG. **21** and FIG. **22**, in different ground structures, the antenna **20** of the bluetooth earphone **100** forms equivalent currents **3*d*** in different directions, and the radiation field patterns **51** formed by the antenna **20** are complementary. The bluetooth earphone **100** may switch the ground structures of the circuit board **40** to change locations of the radiation null **52** and the radiation intensity point **53** of the radiation field pattern **51** of the antenna **20**. Therefore, the antenna **20** has no obvious radiation null **52** in a radiation direction, and antenna gains of the antenna **20** in all directions are relatively even, thereby improving communication quality.

FIG. **23**A is a simulation diagram of a radiation field pattern of the bluetooth earphone **100** when the circuit board **40** shown in FIG. **20** is switched to a first ground structure. FIG. **23**B is a simulation diagram of a radiation field pattern of the bluetooth earphone **100** when the circuit board **40** shown in FIG. **20** is switched to a second ground structure. FIG. **23**A and FIG. **23**B illustrate again, by using simulation diagrams, the radiation field patterns of the antenna **20** of the bluetooth earphone **100** corresponding to the first ground structure and the second ground structure, and the radiation field patterns of the antenna **20** corresponding to different ground structures are complementary.

As shown in FIG. **23**A, when the circuit board **40** switches to the first ground structure, the switch **446** is off, a small part of the second grounding branch **44** may participate in radiation, and a proportion of radiation participation is obviously smaller than that of other currents in a resonance state (namely, the first current and the second current). Therefore, a direction of an effective radiation current (a composed current of all the radiation participation currents) of the antenna **20** rotates a little counterclockwise relative to the equivalent current **3*d*** in FIG. **21**. Adaptively, the direction of the radiation field pattern of the antenna **20** rotates counterclockwise relative to the radiation field pattern in FIG. **21**.

FIG. **24** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **20** in some embodiments.

The circuit board **40** further includes a third end part **406** and a third connection part **407**. The third end part **406** is located at the connecting section **21** of the earphone handle part **2**, or at an end of the bottom section **22** of the earphone handle part **2** that is close to the connecting section **21** of the earphone handle part **2**, and the third end part **406** is connected to or close to the second connection part **403**. When the third end part **406** is connected (for example, welded or connected by conductive adhesive) to the second connection part **403**, an electrical connection is formed therebetween. That the third end part **406** is disposed close to the second connection part **403** means that the third end part **406** touches the second connection part **403**, or that the third end part **406** does not touch the second connection part **403** but a small gap exists therebetween, and electrical coupling is formed between the third end part **406** and the second connection part **403**. One end of the third connection part **407** is connected to the third end part **406**, and the other end of the third connection part **407** is connected to the feeding part **401**. An end of the second branch **445** that is away from the ground plane **42** extends to the third end part **406** through the third connection part **407**. In this case, as shown by a dot-dashed line in FIG. **20**, an end of the second branch **445** that is away from the ground plane **42** is connected or coupled to an end of the first branch **444** that is away from the ground plane **42**.

In some other embodiments, a carrier medium of the second branch **445** may be different from that of the third end part **406** and the third connection part **407**. In this case, a structure of the circuit board **40** may be adjusted accordingly. Implementation of the carrier medium of the second branch **445** is not strictly limited.

In some embodiments, for a method for adjusting the electrical lengths of the first grounding branch **43** and the second grounding branch **44** by the circuit board **40**, refer to the foregoing embodiments. For example, as shown in FIG. **20**, the electrical lengths of the first grounding branch **43** and the second grounding branch **44** are adjusted by connecting a low-pass high-resistance element in series. The first grounding branch **43** is connected in series to a first low-pass high-resistance element **433**. The second grounding branch **44** is connected in series to a second low-pass high-resistance element **443**, and the second low-pass high-resistance element **443** is disposed in series with the first branch **444** and is located at a side of the first branch **444** that is away from the ground plane **42**. The first low-pass high-resistance element **433** and the second low-pass high-resistance element **443** are configured to allow passage of a current whose frequency band is lower than the bluetooth signal frequency band and prevent passage of a current whose frequency band is close to the bluetooth signal frequency band. In some other embodiments, the electrical length of the first grounding branch **43** may be adjusted by bending or stretching a wiring arrangement part (for example, the first connection part **402**) of the circuit board **40**. The electrical length of the second grounding branch **44** may be adjusted by bending or stretching a wiring arrangement part (for example, the second connection part **403** and the second end part **405**) of the circuit board **40**.

In some embodiments, the earpiece module **60** is connected to the first grounding branch **43**. The first grounding branch **43** may serve as a current return path of the antenna **20** and may also serve as a reference ground for a low frequency signal of the earpiece module **60**. A first microphone module **90** is connected to the second grounding branch **44**. The second grounding branch **44** may serve as a current return path of the antenna **20** and may also serve as a reference ground for a low frequency signal of the first microphone module **90**.

FIG. **25** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **2** in still another embodiment. Most content of the circuit board **40** in this embodiment that is the same as that of the circuit board **40** in the foregoing embodiments is not described again. A major difference between this embodiment and the foregoing embodiments lies in that one end of the third connection part **407** is connected to the third end part **406**, and the other end of the third connection part **407** is connected to the second connection part **403**. In this case, as shown by a dot-dashed line in FIG. **25**, an end of the second branch **445** that is away from the ground plane **42** is connected or coupled to an end of the first branch **444** that is away from the ground plane **42**.

FIG. **26** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **25** in some embodiments. The third connection part **407** is connected to an end of the second connection part **403** that is close to the feeding part **401**. After the circuit board **40** is bent, the third end part **406** is fastened to a side of the second connection part **403** facing the feeding part **401**. The second branch **445** located at the third connection part **407** and the third end part **406** can effectively shorten an electrical length of the second grounding branch **44**, to meet an electrical length requirement.

FIG. **27** is a schematic diagram of a structure of the circuit board **40** shown in FIG. **25** in some other embodiments. The third connection part **407** is connected to an end of the second connection part **403** that is close to the feeding part **401**. After the circuit board **40** is bent, the third end part **406** is close to the second connection part **403** and is located at a side of the second connection part **403** facing the feeding part **401**. In the bluetooth earphone **100**, the third end part **406** is located between the battery **70** (refer to the location of the battery **70** in FIG. **3**) and the second connection part **403**. The third end part **406** has a length to form strong coupling with the second connection part **403**, so that the second branch **445** located at the third connection part **407** and the third end part **406** can effectively shorten an electrical length of the second grounding branch **44**, to meet an electrical length requirement.

The foregoing descriptions are merely implementations, but are not intended to limit the protection scope. Any variation or replacement readily figured out by a person skilled in the art shall fall within the scope of the embodiments. When no conflict occurs, the embodiments and the features in the embodiments may be mutually composed.

What is claimed is:

1. A bluetooth earphone comprising:
- an earbud part, wherein the earbud part is provided with an earpiece module;
- an earphone handle part, further comprising:
  - a connecting section connected to the earbud part,
  - a top section and a bottom section located at both sides of the connecting section, wherein the bottom section of the earphone handle part is provided with a first microphone module;
- an antenna, wherein the antenna extends from the connecting section of the earphone handle part to the top section of the earphone handle part; and
- a circuit board further comprising:
  - a feeding part located at the connecting section of the earphone handle part,
  - a first end part located at the earbud part,
  - a first connection part that connects the feeding part and the first end part,
  - a second end part located at the bottom section of the earphone handle part,
  - a second connection part that connects the feeding part and the second end part,
    - a feeding pad located at the feeding part and coupled to the antenna,
    - a ground plane located at the feeding part and spaced from the feeding pad,
    - a first grounding branch wherein one end of the first grounding branch is connected to the ground plane, the other end of the first grounding branch extends to the first end part, and the first grounding branch is connected in series to a first switch, and
    - a second grounding branch, wherein one end of the second grounding branch is connected to the ground plane, the other end of the second grounding branch extends to the second end part, and the second grounding branch is connected in series to a second switch.

2. The bluetooth earphone according to claim **1**, wherein the antenna is configured to form a first current; and
- when the first switch is on and the second switch is off, the first grounding branch is configured to form a second current, wherein the second current and the first current compose an equivalent current in a resonant mode; or
- when the second switch is on and the first switch is off, the second grounding branch is configured to form a third current, wherein the third current and the first current compose the equivalent current in the resonant mode.

3. The bluetooth earphone according to claim **2**, wherein when the first switch is on and the second switch is on, the first grounding branch is configured to form a second current, and the second grounding branch is configured to form a third current, wherein the first current, the second current, and the third current compose the equivalent current in the resonant mode.

4. The bluetooth earphone according to claim **1**, wherein the first switch is located at the feeding part or at an end of the first connection part that is close to the feeding part, and the second switch is located at the feeding part or at an end of the second connection part that is close to the feeding part.

5. The bluetooth earphone according to claim **1**, wherein the first grounding branch is further connected in series to a first choke inductor, the first choke inductor is disposed in parallel with the first switch, and the earpiece module is connected to the first grounding branch.

6. The bluetooth earphone according to claim **1**, wherein the second grounding branch is further connected in series to a second choke inductor, the second choke inductor is disposed in parallel with the second switch, and the first microphone module is connected to the second grounding branch.

7. The bluetooth earphone according to claim **6**, wherein the bluetooth earphone further comprises:

a chip located at the earbud part and connected to the circuit board, and the circuit board further comprises: a first low-frequency signal line, and

a second low-frequency signal line, wherein one end of the first low-frequency signal line is connected to the chip, the other end of the first low-frequency signal line extends to the first end part, the first low-frequency signal line is connected in series to a third choke inductor, and the earpiece module is connected to the first low-frequency signal line; and

one end of the second low-frequency signal line is connected to the chip, the other end of the second low-frequency signal line extends to the second end part, the second low-frequency signal line is connected in series to a fourth choke inductor, and the first microphone module is connected to the second low-frequency signal line.

8. The bluetooth earphone according to claim **1**, wherein the second grounding branch is further connected in series to a second low-pass high-resistance element, and the second low-pass high-resistance element is disposed in series with the second switch and located at a side of the second switch that is away from the ground plane.

9. The bluetooth earphone according to claim **1**, wherein the second connection part comprises a plurality of sequentially connected regions that comprise one or more flat regions and one or more bent regions.

10. A bluetooth earphone comprising:

an earbud part, wherein the earbud part is provided with an earpiece module;

an earphone handle part, further comprising:

a connecting section connected to the earbud part,

a top section and a bottom section located at both sides of the connecting section, wherein the bottom section of the earphone handle part is provided with a first microphone module,

an antenna, wherein the antenna extends from the connecting section of the earphone handle part to the top section of the earphone handle part, and

a circuit board, further comprising:

a feeding part located at the connecting section of the earphone handle part,

a first end part located at the earbud part,

a first connection part that connects the feeding part and the first end part,

a second end part located at the bottom section of the earphone handle part, and

a second connection part that connects the feeding part and the second end part,

a feeding pad located at the feeding part and coupled to the antenna,

a ground plane located at the feeding part and spaced from the feeding pad,

a first grounding branch, wherein one end of the first grounding branch is connected to the ground plane and the other end of the first grounding branch extends to the first end part, and

a second grounding branch, wherein one end of the second grounding branch is connected to the ground plane, the other end of the second grounding branch extends to the second end part, the second grounding branch is connected in series to a first branch and further comprises a second branch, one end of the second branch is connected to one end of the first branch and the other end of the second branch is connected or coupled to the other end of the first branch, the second branch is connected in series to a switch, and the second branch is shorter than the first branch.

11. The bluetooth earphone according to claim **10**, wherein the antenna is configured to form a first current; and

when the switch is off, the first grounding branch is configured to form a second current, wherein the second current and the first current compose an equivalent current in a resonant mode; or

when the switch is on, the first grounding branch is configured to form a second current, and the second grounding branch is configured to form a third current, wherein the first current, the second current, and the third current compose the equivalent current in the resonant mode.

12. The bluetooth earphone according to claim **10**, wherein the circuit board further comprises:

a third end part located at the connecting section of the earphone handle part or at an end of the bottom section of the earphone handle part that is close to the connecting section of the earphone handle part and is connected to the second connection part or is disposed close to the second connection part, and

a third connection part, wherein, one end of the third connection part is connected to the third end part and the other end of the third connection part is connected to the feeding part or the first connection part, and one end of the second branch that is away from the ground plane extends to the third end part through the third connection part.

13. The bluetooth earphone according to claim **10**, wherein the earpiece module is connected to the first grounding branch, and the first microphone module is connected to the second grounding branch.

14. The bluetooth earphone according to claim **10**, wherein the second grounding branch is connected in series to a second low-pass high-resistance element that is disposed in series with the first branch and is located at a side of the first branch that is away from the ground plane.

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